ROYAL SOCIETY.

REPORT

OF

THE COMMITTEE OF

PHYSICS, INCLUDING METEOROLOGY,

ON THE

OBJECTS OF SCIENTIFIC INQUIRY

IN THOSE SCIENCES.

APPROVED BY

THE PRESIDENT AND COUNCIL.

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REPORT.

PHYSICS AND METEOROLOGY.

The Committee of Physics, including Meteorology, are very strongly impressed with the number and importance of the desiderata in physical and meteorological science, which may wholly or in part be supplied by observations which may be expected from the zeal and industry of travellers, residents in foreign countries, and others whose position may give them favourable opportunities of stimulating research on the part of those in their respective departments. While they wish therefore to omit nothing in their enumeration of those objects which appear to them deserving of attentive inquiry on sound scientific grounds, and from which consequences may be drawn of real importance, either for the settlement of disputed questions, or for the advancement of knowledge in any of its branches,—they deem it equally their duty to omit or pass lightly over several points which, although not without a certain degree of interest, may yet be regarded in the present state of science rather as matters of abstract curiosity than as affording data for strict reasoning; as well as others, which may be equally well or better elucidated by inquiries instituted at home and at leisure.

1. TERRESTRIAL MAGNETISM.

Terrestrial Magnetism will be considered: 1st, as regards those accessions to our knowledge which may be supplied by observations to be made, independently of any concert with or co-operation of other observers; and 2ndly, as regards those which depend on and require such concert; and are therefore to be considered with reference to the observations about to be carried on simultaneously in the fixed magnetic observatories established by Her Majesty's Government, and in the other similar observatories, both public and private, in Europe, India, and elsewhere, with which it is intended to open and maintain a correspondence.

Now it may be observed, that these two classes of observations naturally refer themselves to two chief branches into which the

science of terrestrial magnetism in its present state may be subdivided, and which bear a certain analogy to the theories of the elliptic movements of the planets, and of their periodical and secular perturbations. The first comprehends the actual distribution of the magnetic influence over the globe, at the present epoch, in its mean or average state, when the effects of temporary fluctuations are either neglected, or eliminated by extending the observations over a sufficient time to neutralize their effects. The other comprises the history of all that is not permanent in the phenomena, whether it appear in the form of momentary, daily, monthly, or annual change and restoration, or in progressive changes not compensated by counter changes, but going on continually accumulating in one direction, so as in the course of many years to alter the mean amount of the quantities observed. These last-mentioned changes hold the same place, in the analogy above alluded to, with respect to the mean quantities and temporary fluctuations, that the secular variations in the planetary movements must be regarded as holding, with respect to their mean orbits on the one hand, and their perturbations of brief period on the other.

There is, however, this difference, that in the planetary theory all these varieties of effect have been satisfactorily traced up to a single cause, whereas in that of terrestrial magnetism this is so far from being demonstrably the case, that the contrary is not destitute of considerable probability. In fact, the great features of the magnetic curves, and their general displacements and changes of form over the whole surface of the earth, would seem to be the result of causes acting in the interior of the earth, and pervading its whole mass; while the annual and diurnal variations of the needle, with their train of subordinate periodical movements, may, and very probably do, arise from and correspond to electric currents produced by periodical variations of temperature at its surface, due to the sun's position above the horizon, or in the ecliptic, modified by local causes; while local or temporary electric discharges, due to thermic, chemical, or mechanical causes, acting in the higher regions of the atmosphere, and relieving themselves irregularly or at intervals, may serve to render account of those unceasing, and as they seem to us casual movements, which recent observations have placed in so conspicuous and interesting a light. The electrodynamic theory, which refers all magnetism to electric currents, is silent as to the causes of those currents, which may be various, and which only the analysis of their effects can teach us to regard as internal, superficial, or atmospheric.

It is not merely for the use of the navigator that charts, giving a general view of the lines of Magnetic Declination, Inclination, and Intensity, are necessary. Such charts, could they really be depended on, and were they in any degree complete, would be of the most eminent use to the theoretical inquirer, not only as general directions in the choice of empirical formulæ, but as powerful instruments for facilitating numerical investigation, by the choice

they afford of data favourably arranged; and above all, as affording decidedly the best means of comparing any given theory with observation. In fact, upon the whole, the readiest, and beyond comparison the fairest and most effectual mode of testing the numerical applicability of a theory of terrestrial magnetism, would be, not servilely to calculate its results for given localities, however numerous, and thereby load its apparent errors with the real errors, both of observation and of local magnetism; but to compare the totality of the lines in our charts with the corresponding lines, as they result from the formulæ to be tested, when their general agreement or disagreement will not only show how far the latter truly represent the facts, but will furnish distinct indications of the modifications they require.

Unfortunately for the progress of our theories, however, we are yet very far from possessing charts even of that one element, the Declination, most useful to the navigator, which satisfy these requisites; while as respects the others (the Inclination and Intensity) the most lamentable deficiencies occur, especially in the Antarctic regions. To make good these deficiencies by the continual practice of every mode of observation appropriate to the circumstances in which the observer is placed throughout a voyage, will be one of the great objects to which attention must be directed. And first—

At sea.—We are not to expect from magnetic observations made at sea the precision of which they are susceptible on land. Nevertheless, it has been ascertained that not only the Declination, but the Inclination and Intensity can be observed, in moderate circumstances of weather and sea, with sufficient correctness, to afford most useful and valuable information, if patience be bestowed, and proper precautions adopted. The total intensity, it is ascertained, can be measured with some considerable degree of certainty by the adoption of a statical method of observation recently devised by Mr. Fox. And when it is recollected that but for such observations the whole of that portion of the globe which is covered by the ocean must remain for ever a blank in our charts, it will be needless further to insist on the necessity of making a daily series of magnetic observations, in all the three particulars abovementioned, whenever weather and sea will permit, an essential feature in the business of a voyage. Magnetic observations at sea will, of course, be affected by the ship's magnetism, and this must be eliminated to obtain results of any service. To this end,

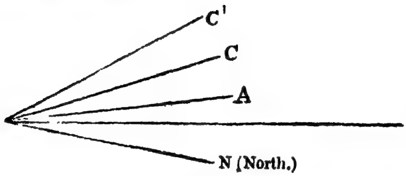
First. Every series of observations made on board should be accompanied with a notice of the direction by compass of the ship's head at the time.

Secondly. Previous to sailing, a very careful series of the apparent deviations, as shown by two compasses permanently fixed, (the one as usual, the other in a convenient position, considerably more forward in the ship,) in every position of the ship's head, as compared with the real position of the ship, should be made and recorded, with a view to attempt procuring the constants of the ship's action ac-

cording to M. Poisson's theory*; and this process should be repeated on one or more convenient occasions during the voyage; and, generally, while at anchor, every opportunity should be taken of swinging round the ship's head to the four cardinal points, and executing in each position a complete series of the usual observations.

Thirdly. Wherever magnetic instruments are landed and observations made on *terra firma*, or on ice, the opportunity should be

* Note on M. Poisson's theory of the deviation produced in the direction of the compass by the iron of the ship.



Let G x be the axis of the ship, x lying towards the ship's head.
G the centre of gravity of the compass.
G N the meridian, N the north.

Let A be the *south pole* of the dipping needle, that is the extremity of the needle which dips *beneath* the horizontal plane in our hemisphere, let C be the projection of the point A upon a horizontal plane, so that G C is the magnetic meridian. Let the angle A G C $= \theta$, θ varying from -90° to $+90^\circ$, being positive when the south pole A is *beneath* the horizontal plane, and negative in the contrary case.

Let C G N $= \psi$, this angle (*variation*) which is the azimuth of the vertical plane C G A may extend from -180° to $+180^\circ$, and is to be considered *positive* or *negative* according as the line G C falls to the *west* or to the *east* of the line G N, or this angle may be considered to vary from 0 to 360°, going from north to south through *west* and returning from south to north by *east*.

Let G C′ be the direction of a horizontal needle, so that C′ G C is the *local attraction*.

Let $x\,\mathrm{G\,C'} = \zeta$ $\qquad$ $\mathrm{C'G\,C} = \delta$ $\qquad$ $x\,\mathrm{G\,C} = \zeta - \delta$.

$\mathrm{N\,G\,C'} = \psi'$ $\qquad$ $\delta = \psi' - \psi$.

Let ω be the azimuth of the principal section of the ship reckoned from G N towards the *west*,

$x\,\mathrm{G\,N} = \omega$ $\qquad$ $\psi' - \omega = \zeta$ $\qquad$ $\psi - \omega = \zeta - \delta$

M. Poisson arrives at the following equation, *Conn. de Temps*, 1841, p. 146, and *Mem. de l'Institut*, tom. xvi. p. 529.

$$\left.\begin{aligned}&[\mathrm{A'}\cos\theta\cos(\psi-\omega)+\mathrm{B}\cos\theta\sin(\psi-\omega)+\mathrm{C}\sin\theta]\sin\zeta\\&=[\mathrm{D}\cos\theta\cos(\psi-\omega)+\mathrm{E'}\cos\theta\sin(\psi-\omega)+\mathrm{F}\sin\theta]\cos\zeta\end{aligned}\right\}\quad . \quad (1.)$$

A′, B, C, D, E′, F are constants, if therefore

$$\frac{\mathrm{B}}{\mathrm{A'}} = c,\ \frac{\mathrm{C}}{\mathrm{A'}} = a,\ \frac{\mathrm{D}}{\mathrm{A'}} = d,\ \frac{\mathrm{E'}}{\mathrm{A}} = b,\text{ and }\frac{\mathrm{F}}{\mathrm{A'}} = e$$

$$\cos(\zeta-\delta)\sin\zeta + c\sin(\zeta-\delta)\sin\zeta + a\tan\theta\cos\zeta,$$
$$= d\cos(\zeta-\delta)\cos\zeta + b\sin(\zeta-\delta)\cos\zeta + e\tan\theta\cos\zeta.$$

in which equation a, b, c, d, e are constants, which must be determined from observations at some one place, and which continue invariable as long as the position of the iron in the ship remains unaltered. In order to do this the local attractions corresponding to every azimuth of the ship's head must be obtained and may be inserted in a table, or at least they must be found in sufficient number to afford any others by interpolation. The manner of obtaining such data from ob-

seized of going through the regular series on ship-board with more than usual diligence and care, so as to establish, by actual experiment in the only unexceptionable manner, the nature and amount of the corrections due to the ship's action for that particular geographical position, and by the assemblage of all such observations to afford data for concluding them in general.

Fourthly. No change possible to be avoided should be made in the disposition of considerable masses of iron in ships during the whole voyage; but if such change be necessary, it should be noted.

servation is described in the small code of instructions which accompanies Mr. Barlow's plate, and is also given in the Nautical Magazine.

$\psi =$ $\theta =$

Direction of ship's head. ω. x G N.	Local attraction. δ. C′ G C.	Observed. ζ. x G C′.	$\zeta - \delta$. x G C.

N.B. *This Table to be filled up from observation.*

If $\zeta = 0$,

$$-\sin\delta_1 = \frac{d\cos\delta_1 + e\tan\theta}{b}$$

if $\zeta = 180°$

$$-\sin\delta_2 = \frac{-d\cos\delta_2 + e\tan\theta}{b}$$

if $\zeta = 90°$

$$-\sin\delta_3 = c\cos\delta_3 + a\tan\delta.$$

if $\zeta = 270°$

$$\sin\delta_4 = -c\cos\delta_4 + a\tan\theta$$

from these four equations, if $d = m\,b$, $e = n\,b$, a, c, m and n may easily be found, and b may be then obtained from any other known deviation.

By solving equation (1.) with respect to $\tan\zeta$, the angle ζ may be found corresponding to the angle $\zeta - \delta$,

$$\tan\zeta = \frac{d\cos(\zeta-\delta) + b\sin(\zeta-\delta) + e\tan\theta}{\cos(\zeta-\delta) + c\sin(\zeta-\delta) + a\tan\theta}.$$

Afterwards, by interpolation or reversion, the angle $\zeta - \delta$ may be obtained corresponding to the *observed angle* ζ, and a table of double entry formed, giving the *local attraction* for every value of ζ, the *arguments* of the table being the *observed angle* ζ and the *dip*. This table, according to the theory of M. Poisson, ought to continue available in all quarters of the globe so long as the disposition of the masses of iron in the ship remains unaltered.

If when the ship's head is on the magnetic north and south, no effects arise from

Fifthly. When a traveller crosses the magnetic line of no dip it would be desirable to go through the observation for the dip with the instrument successively placed in a series of different magnetic azimuths, by which the influence of the ship's magnetism in a vertical direction will be placed in evidence.

On land, or on ice.—If the completeness and excellence of the instruments with which the traveller is furnished authorize confidence in the results obtained by their use, the redetermination of the magnetic elements at points where they are already considered as ascertained, will be scarcely less desirable than their original determination at stations where they have never before been observed. This is the more to be insisted on, as lapse of time changes these elements in some cases with considerable rapidity; and it is therefore of great consequence that observations to be compared should be as nearly cotemporary as possible, and that data should be obtained for eliminating the effects of secular variations during short intervals of time, so as to enable us to reduce the observations of a series to a common epoch.

On the other hand it cannot be too strongly recommended to the scientific navigator, studiously to seek every opportunity of landing

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local attraction, as was the case in the experiments of Captain Flinders, $\delta_1 = 0$, $\delta_2 = 0$, and hence $d = 0$, $e = 0$.

If the iron is symmetrically situate about the axis of the ship, then according to M. Poisson $c = 0$, $d = 0$, $e = 0$.

$$\cos(\zeta - \delta)\sin\zeta + a\tan\theta\sin\zeta = b\sin(\zeta - \delta)\cos\zeta. \quad . \quad . \quad . \quad . \quad . \quad . \qquad (2.)$$

Conn. de Temps, p. 150.

$$\tan\zeta = \frac{b\sin(\zeta - \delta)}{\cos(\zeta - \delta) + a\tan\theta}.$$

$$\sin\delta = \frac{\sin\zeta\left\{(b-1)\cos\zeta - a\tan\theta\right\}}{1 + (b-1)\cos^2\zeta} \quad \text{nearly.}$$

If δ' is the *local attraction*, ζ' the magnetic bearing of any compass in any other distant part of the ship, or of the same compass after the disposition of the iron has been changed,

$$\cos(\zeta' - \delta')\sin\zeta' + a'\tan\theta\sin\zeta' = b'\sin(\zeta' - \delta')\cos\zeta'$$

but $\zeta' - \delta' = \zeta - \delta$

hence $\quad \cos(\zeta - \delta)\sin\zeta + a'\tan\theta\sin\zeta' = b'\sin(\zeta - \delta)\cos\zeta'$

eliminating $\tan\theta$,

$$\tan(\zeta - \delta) = \frac{(a' - a)\sin\zeta'\sin\zeta}{a'b\sin\zeta'\cos\zeta - ab'\sin\zeta\cos\zeta'}.$$

From this equation it may be possible to compute a table of double entry, giving the local attraction without knowing the dip, the arguments of the table being the *observed angles* ζ of two compasses situate in different parts of the vessel. This table ought to continue available so long as the disposition of the masses of iron remains unaltered. The two compasses must of course be so distant as to have no sensible effect upon each other.

The theory of Mr. Barlow's plate, according to M. Poisson, depends upon the practicability of so disposing the iron in the vessel as to give to the constants a and b in equation (2.) the particular values $a = 0$, $b = 1$.

on points (magnetically speaking) unknown, and determining the elements of those points with all possible precision. Nor should it be neglected, whenever the slightest room for doubt subsists, to determine at the same time the geographical position of the stations of observation in latitude and longitude. When the observations are made on ice, it is needless to remark that this will be universally necessary.

With this general recommendation, it will be unnecessary to enumerate particular localities. In fact, it is impossible to accumulate too many. Nor can it be doubted that in the course of antarctic exploration, many hitherto undiscovered points of land will be encountered, each of which will, of course, become available as a magnetic station, according to its accessibility and convenience.

There are certain points in the southern regions which offer great and especial interest in a magnetic point of view. These are, first, the south magnetic pole (or poles), meaning thereby the point or points in which the horizontal intensity vanishes and the needle tends vertically downwards; and secondly, the points of maximum intensity, which, to prevent the confusion arising from a double use of the word poles, we may provisionally term magnetic *foci*.

It may here be mentioned, that no scientific datum of this description, nor any attempt to attain very high southern latitudes, can be deemed important enough to be made a ground for exposing to *extraordinary* risk the lives of brave and valuable men. The magnetic pole, though not attained, may yet be pointed to by distinct and unequivocal indications; viz. by the approximation of the dip to 90°; and by the convergence of the magnetic meridians on all sides towards it. If such convergence be observed over any considerable region, the place of the pole may thence be deduced, though its locality may be inaccessible.

M. Gauss, from theoretical considerations, has recently assigned a probable position in lon. 146° E., lat. 66° S., to the southern magnetic pole, denying the existence of two poles of the same name, in either hemisphere, which, as he justly remarks, would entail the necessity of admitting also a third point, having some of the chief characters of such a pole intermediate between them. This may be made obvious without following out his somewhat intricate demonstration, by simply considering, that if a needle be transported from one such pole to another of the same name, it will *begin* to deviate from perpendicularity *towards* the pole it has quitted, and will end in attaining perpendicularity again, after pointing in the latter part of its progress obliquely *towards the pole to which it is moving*, a sequence of things impossible without an intermediate passage through the perpendicular direction.

It is not improbable that the point indicated by M. Gauss will prove accessible; at all events it cannot but be approachable sufficiently near to test by the convergence of meridians the truth of the indication; and as his theory gives within very moderate limits of error the true place of the northern pole, and otherwise represents

the magnetic elements in every explored region with considerable approximation, it is but reasonable to hope that this point may be decided in Captain Ross's voyages. Should the decision be in the negative, i. e. should none of the indications characterizing the near vicinity of the magnetic pole occur in that region, it will be to be sought; and a knowledge of its real locality will be one of the distinct scientific results which may be confidently hoped from that Expedition, and which can only be attained by circumnavigating the antarctic pole compass in hand.

The actual attainment of a *focus* of maximum intensity is rendered difficult by the want of some distinct character by which it can be known, previous to trial, in which direction to proceed, when after increasing to a certain point the intensity begins again to diminish. The best rule to be given, would be (supposing circumstances would permit it) on perceiving the intensity to have become nearly stationary in its amount, to turn short and pursue a course at right angles to that just before followed, when a change could not fail to occur, and indicate by its direction towards which side the focus in question were situated.

Another, and as it would appear, a better mode of conducting such a research, would be, when in the presumed neighbourhood of a focus of maximum intensity, to run down two parallels of latitude or two arcs of meridians separated by an interval of moderate extent, observing all the way in each, by which observations, when compared, the concavities of the isodynamic lines would become apparent, and perpendiculars to the chords, intersecting in or near the foci, might be drawn.

Two foci or points of maximum *total* intensity are indicated by the general course of the lines in Major Sabine's chart in the Southern Hemisphere, one about long. 140° E., lat. 47° S., the other more obscurely in long. 235° E., lat. 60° S., or thereabouts. Both these points are certainly accessible; and should the course of the navigator lead not far from each of them, they might be visited with advantage by a course calculated to lead directly across the isodynamic ovals surrounding them.

Pursuing the course of the isodynamic lines in the chart above mentioned, it appears that one of the two points of *minimum* total intensity, which must exist, if that chart be correct, may be looked for nearly about lat. 25° S., long. 12° W., and that the intensity at that point is probably the least which occurs over the whole globe. Now this point does not lie much out of the direct course usually pursued by vessels going to the Cape. It would therefore appear desirable to pass directly over it, were it only for the sake of determining by direct measure the least magnetic intensity at present existing on the earth, an element not unlikely to prove of importance in the further progress of theoretical investigation. Excellent opportunities may be afforded for the investigation of all these points, and for making out the true form of the isodynamic ovals of the South Atlantic, both in beating up for St. Helena, and in passing

from thence to the Cape; in the course of which, the point of least intensity will, almost of necessity, have to be crossed, or at least approached very near.

Nor is the theoretical line indicated by M. Gauss as dividing the northern and southern regions, in which free magnetism may be regarded as superficially distributed, undeserving of attention. That line cuts the equator in 6° east longitude, being inclined thereto (supposing it a great circle) 15°, by which quantity it recedes from the equator northward in going towards the west of the point of intersection. Observations made at points lying in the course of this line may hereafter prove to possess a value not at present contemplated.

As a theoretical datum, the horizontal intensity has been recommended by M. Gauss, in preference to the total, not only as being concluded from observations susceptible of great precision, but as affording immediate facilities for calculation. As it cannot now be long before the desideratum of a chart of the horizontal intensity is supplied, the maxima and minima of this element may also deserve especial inquiry, and may be ascertained in the manner above pointed out.

The maxima of horizontal intensity are at present undetermined by any direct observation. They must of necessity, however, lie in lower magnetic latitudes than those of the total intensity, as its minima must in higher; and from such imperfect means as we have of judging, the situations of the maxima may be stated as occurring in

20° N.	80° E.	I.
7 N.	260 E.	II.
3 S.	130 E.	III.
10 S.	180 E.	IV.

Observations have been made of the horizontal intensity in the vicinities of II. and III., and are decidedly the highest which have been observed anywhere.

In general, in the choice of stations for determining the values of the three magnetic elements, it should be borne in mind, that the value of each new station is directly proportional to its remoteness from those already known. Should any doubt arise, therefore, as to the greater or less eligibility of particular points, a reference to the existing magnetic maps and charts, by showing where the known points of observation are most sparingly distributed, will decide it.

For such magnetic determinations as those above contemplated, the instruments hitherto in ordinary use, with the addition of Mr. Fox's apparatus for the statical determination of the intensity, will suffice; the number of the sea observations compensating for their possible want of exactness. The determinations which belong to the second branch of our subject,—viz. those of the secular changes, of the diurnal and other periodical variations, and of the momentary fluctuations of the magnetic forces,—require, in the present state of

our knowledge, the use of those more refined instruments recently introduced, and to be presently described.

The variations to which the earth's magnetic force is subject, at a given place, may be classed under three heads, namely, 1. the *irregular* variations, or those which apparently observe no law; 2. the *periodical* variations, whose amount is a function of the *hour angle* of the sun, or of his *longitude*; and 3. the *secular* variations, which are either slowly progressive, or else return to their former values in periods of very great and unknown magnitude.

The recent discoveries connected with the *irregular* variations of the magnetic declination, have given to this class of changes a prominent interest. In the year 1818 M. Arago made, at the Observatory of Paris, a valuable and extensive series of observations on the declination changes; and M. Kupffer having about the same time undertaken a similar research at Kasan, a comparison of the results led to the discovery that the perturbations of the needle were *synchronous* at the two places, although these places differed from one another by more than forty-seven degrees of longitude. This seems to have been the first recognition of a phenomenon, which now, in the hands of Gauss and those who are labouring with him, appears likely to receive a full elucidation.

To pursue this phenomenon successfully, and to promote in other directions the theory of terrestrial magnetism, it was necessary to extend and vary the stations of observation, and to adopt at all a common plan. Such a system of simultaneous observations was organized by Von Humboldt in the year 1827. Magnetic stations were established at Berlin and Freyberg: and the Imperial Academy of Russia entering with zeal into the project, the chain of stations was carried over the whole of that colossal empire. Magnetic *houses* were erected at Petersburg and at Kasan; and magnetic instruments were placed, and regular observations commenced, at Moscow, at Sitka, at Nicolajeff in the Crimea, at Barnaoul and Nertschinsk in Siberia, and even at Pekin. The plan of observation was definitely organized in 1830; and simultaneous observations were made seven times in the year, at intervals of an hour for the space of forty-four hours.

In 1834 M. Gauss turned his attention to the subject of terrestrial magnetism; and having contrived instruments capable of yielding results of an accuracy before unthought of in magnetic researches, he proceeded to inquire into the simultaneous movements of the horizontal needle at distant places. At the very outset of this inquiry he discovered the fact, that the synchronism of the perturbations was not confined (as had been hitherto imagined) to the larger and extraordinary changes; but that even the minutest deviation at one place of observation had its counterpart at the other. Gauss was thus led to organize a plan of simultaneous observations, (not at intervals of an hour, as before, but) at the short intervals of five minutes. These were carried on through twenty-four hours six*

* Recently reduced to *four*.

times in the year; and magnetic stations taking part in the system were established at Altona, Augsburg, Berlin, Bonn, Brunswick, Breda, Breslau, Cassel, Copenhagen, Kracow, Dublin, Freyberg, Göttingen, Greenwich, Halle, Kasan, Leipsic, Marburg, Milan, Munich, Naples, St. Petersburg, and Upsala.

Extensive as this plan appears, there is much yet remaining to be accomplished. The stations, numerous as they are, embrace but a small portion of the earth's surface; and what is of yet more importance, none of them are situated in the neighbourhood of those *singular points* or curves on the earth's surface, where the *magnitude* of the changes may be expected to be excessive, and perhaps even their *direction* inverted. In short, a wider system of observation is required to determine whether the amount of the changes (which is found to be very different in different places) is dependent simply on the *geographical* or on the *magnetic* co-ordinates of the place; whether, in fact, the variation in that amount be due to the greater or less distance of a disturbing centre, or to the modifying effect of the mean magnetic force of the place, or to both causes acting conjointly. In another respect also, the plan of the simultaneous observations admits of a greater extension. Until lately the movements observed have been only those of the magnetic *declination*, although there can be no doubt that the *inclination* and the *intensity* are subject to similar perturbations. Recently, at many of the German stations, the *horizontal component* of the intensity has been observed, as well as the declination; but the determination of another element is yet required, before we are possessed of all the data necessary in this most interesting research.

The Magnetic Observatories about to be established in the British Colonies, by the liberality of the Government and of the East India Company, will (it is hoped) supply in a great measure these desiderata. The stations are widely scattered over the earth's surface, and are situated at points of prominent interest with regard to the Isodynamic and Isoclinal lines. The point of *maximum intensity* in the northern hemisphere is *in* Canada; the corresponding maximum in the southern hemisphere is *near* Van Diemen's Land; St. Helena is close to the line of *minimum intensity*; and the Cape of Good Hope is of importance on account of its southern latitude. Again, in India, Madras and Singapore are in the neighbourhood of the two lines of *minimum intensity* and of *no dip*, which in this region of the globe approach one another; and Simla, in the Himalaya mountains, is a station of interest and importance on account of its great elevation. At each observatory the changes of the *vertical component* of the magnetic force will be observed, as well as those of the *horizontal component* and *declination*; and the variations of the two components of the force being known, those of the *inclination* and of the *force* itself are readily deduced. The simultaneous observations of these three elements will be made at numerous and stated periods, and there is every reason to hope that the directors of many of the European Observatories will take part in the combined system.

But interesting as these phenomena are, they form but a small part of the proper business of an observatory. The *regular* changes (both periodic and secular) are no less important than the irregular; and they are certainly those by which a patient inductive inquirer would seek to ascend to general laws. Even the empirical expression of the laws of these changes cannot fail to be of the utmost value, as furnishing a correction to the absolute values of the magnetic elements, and thereby reducing them to their mean amount.

The hourly changes of the *declination* have been frequently and attentively observed; but with respect to the periodical variations of the other two elements, our information is as yet very scanty. The determination of these variations will form an important part of the duty of Magnetic Observatories; and from the accuracy of which the observations are susceptible, and the extent which it is proposed to give them, there can be no doubt that a very exact knowledge of the empirical laws will be the result.

With respect to the *secular* variations, it might perhaps be doubted whether the limited time during which the observatories will be in operation is adequate to their determination. But it should be kept in mind that the monthly mean corresponding to *each hour of observation* will furnish a separate result; and that the number and accuracy of the results thus obtained may be such, as fully to compensate for the shortness of the interval through which they are followed. A beautiful example of such a result, deduced from three years' observation of the declination, is to be found in the first volume of Gauss's magnetical work, of which a translation is published in the fifth number of Taylor's Scientific Memoirs.

Allusion has been made above to a different system of magnetic elements from that usually chosen. Before proceeding further, therefore, it is necessary to state more fully what those elements are which have been taken as the immediate objects of research; and to describe the instruments which have been adopted for the purpose.

The elements on which the determination of the Earth's Magnetic Force is usually based are, the *declination*, the *inclination*, and the *intensity*. If a vertical plane be conceived to pass through the direction of the force, that direction will be determined when its inclination to the horizon is given, as well as the angle which the plane itself forms with the meridian; and if, in addition to these quantities, we likewise know the number which expresses the ratio of the intensity of the force to some established unit, it is manifest that the force is completely determined.

For many purposes, however, and especially in the delicate researches connected with the *variations* of the magnetic force, a different system of elements is preferable. The intensity being resolved into two portions in the plane of the magnetic meridian, one of them *horizontal* and the other *vertical*, it is manifest that these two components may be substituted for the total intensity and the inclina-

tion; while, at the same time, their changes may be determined with far greater precision. The former variables are connected with the latter by the relations

$$X = R\cos\theta, \qquad Y = R\sin\theta;$$

in which R denotes the intensity, X and Y its horizontal and vertical components, and θ the inclination; and the variations of θ and R are expressed in terms of the variations of X and Y by the formulæ:

$$\Delta\theta = \tfrac{1}{2}\sin 2\theta\left(\frac{\Delta Y}{Y} - \frac{\Delta X}{X}\right);$$

$$\frac{\Delta R}{R} = \cos^2\theta\,\frac{\Delta X}{X} + \sin^2\theta\,\frac{\Delta Y}{Y}.$$

As the instruments required for the observation of these elements are, for the most part, novel in form, it will be useful to give a somewhat detailed account of their construction and various adjustments, before entering on the plan of observation to be pursued.

DECLINATION MAGNETOMETER.

Construction.—The essential part of the declination magnetometer is a magnet bar, suspended by fibres of untwisted silk, and inclosed in a box, to protect it from the agitation of the air. The bar is a rectangular parallelopiped, 15 inches in length, $\frac{7}{8}$ths of an inch in breadth, and $\frac{1}{4}$th of an inch in thickness. In addition to the stirrup by which the bar is suspended, it is furnished with two sliding pieces, one near each end. One of these pieces contains an achromatic lens, and the other a finely-divided scale of glass; the scale being adjusted to the focus of the lens, it is manifest that the apparatus forms a moving collimator, and that its absolute position at any instant, as well as its changes of position from one instant to another, may be read off by a telescope at a distance. The aperture of the lens of this collimator is $1\frac{1}{4}$ inch, and its focal length about 12 inches. Each division of the scale is $\frac{1}{300}$th part of an inch, and the visual angle under which it is seen in the telescope is so considerable, that it may be readily subdivided into tenths by estimation. The corresponding angular quantity is about 43 seconds, and the readings may therefore be made to *four seconds* nearly.

To the suspension thread is attached a small cylindrical bar, the ends of which are of smaller diameter, and support the stirrup which carries the magnet. The apertures in the stirrup, by which it hangs on the cylinder, are of the form of inverted Y's, so that the bearing points are invariable. A second pair of apertures at the other side of the magnet, serves for the purpose of *inversal*; and care has been taken to render the lines connecting the bearing points of each pair of Y's parallel, so that there may be no difference in the amount of torsion of the thread in the two positions of the stirrup. The two pairs of apertures are at different distances from the magnet, in order that the line of collimation may remain nearly at the same

height on inversal, and thus it may not be necessary to alter the length of the suspension thread. The stirrup, and the other sliding pieces, are formed of gun metal.

For the purpose of taking out the torsion of the suspension thread, the apparatus is furnished with a *detorsion bar*, which (with its appendages) is of the same weight as the magnet. It is a rectangular bar of gun-metal, furnished with a stirrup and collimator similar to those of the magnet. A rectangular aperture in the middle receives a small magnet, the use of which is to impart a slight directive force to the suspended bar, without which the final adjustment of detorsion would be tedious and difficult.

The frame-work of the instrument consists of two pillars of copper, 35 inches in height, firmly screwed to a massive marble base. These pillars are connected by two cross pieces of wood, one at the top, and the other 7 inches from the bottom. In the centre of the top piece is the suspension apparatus, and a divided circle used in determining the amount of torsion of the thread. A glass tube (between this and the middle of the lower cross piece) incloses the suspension thread; and a glass cap at top covers the suspension apparatus, and completes the inclosure of the instrument.

The box is cylindrical, its dimensions being 20 inches in diameter by 7 inches in depth. It rests upon the marble slab, and encompasses the pillars; and it is so contrived as to be raised, when necessary, for the purpose of manipulation. There are two apertures in the box, opposite to each other. The aperture in front, used for reading, is covered with a circular piece of parallel glass, attached to a rectangular frame of wood which moves in dovetails; the prismatic error of the glass (if any) is corrected by simply reversing the slider in the dovetails. The opposite aperture is for the illumination of the scale, and is furnished with a sliding piece of wood carrying a moveable mirror.

In addition to the parts abovementioned, the instrument is provided with a second magnet, of the same dimensions as the first, to be used in measurements of absolute intensity; and a copper ring, for the purpose of checking the vibration *.

* The declination magnetometers which were provided for the Antarctic expedition differ from that above described in one or two particulars, which have been necessarily varied in order to enable the observer to read off *very great* deviations.

The magnet has a second stirrup, which is furnished with a mirror, for the purpose of reading the declination changes by reflexion after the method of Gauss. The mirror is attached to a cross, which is fixed to the stirrup; it is kept in its place by three small screws, the heads of which project and hold it; the plane of the mirror may be adjusted by the movement of these screws. The deviation of the line of collimation (which, in this case, is the normal to the surface of the mirror) from the magnetic axis of the bar, is ascertained by *inversal*, the stirrup being provided with a second pair of apertures, in the form of inverted Y's, for the purpose.

There are two graduated scales to be used with the mirror. The first of these is a straight scale, similar to that of Gauss, to be used for moderately large variations. This scale is 4 feet long, and the magnitude of each division is ·04082 of an inch. Every tenth division is numbered 1, 2, 3, &c. up to 100. The divisions are engraved and printed on paper which is attached to a slip of wood by sealing.

Adjustment.—The instrument having been placed on its support, the base is to be levelled, and the whole then fixed in its place. The levelling of the base may conveniently be performed by the aid of a plumb-line hanging in the place of the suspension thread; but no great precision is required in this operation, the chief object of which is that the suspension thread may occupy the middle of the tube, and that the magnet may be central with regard to its support. The suspension thread is then to be formed, and attached at one extremity to the roller of the suspension apparatus, and at the other to the small cylinder which is to bear the stirrup and magnet. Sixteen fibres* of untwisted silk are sufficient to bear double the load without breaking, and will be found to form in other respects a convenient suspension.

These preparations being made, the adjustments are the following:

1. The sliders being placed on the magnet, the scale is to be adjusted to the focus of the lens, and in such a manner that the centre of gravity of the sliders may be near the middle of the bar. The adjustment to focus is readily made, by first adjusting the reading telescope accurately to focus by means of a star, and then using it to view the scale through the object lens of the collimator. The scale will be in the focus of the lens, when it is distinctly seen with the telescope.

2. The magnet is to be connected with the suspension thread by means of the stirrup, and to be moved in the stirrup until it assumes the horizontal position. This adjustment may be conveniently effected by means of the image of the magnet, reflected from the surface of water or mercury, the object and its reflected image being parallel when the former is horizontal. The stirrup is then fastened by its screws, and the magnet wound up to the desired height. As the thread stretches considerably at first, allowance should be made for this in the height.

3.† The magnet is then removed, and the unmagnetic bar (having its collimator similarly adjusted) is to be attached, without its small magnet, and allowed to swing for several hours. The bar having

wax varnish. The second scale is graduated on a complete circle, 6 feet in diameter, and is to be used when the changes (regular or irregular) are excessive. The circle is of wood, and is in the shape of a flat ring, 9 inches in breadth, formed in segments so as to preserve its figure. At the exterior of the ring is a raised edge (also built in segments), on the interior face of which the scale is attached. The scale itself is the same as the former; the numbering of the divisions (every tenth) proceeding from 0 to 100, and then commencing anew.

The aperture in the box is a rectangle, 6 inches long by 2½ inches high, and is covered by a piece of wood sliding in dovetails, having a glass window of the usual size. The glass-cover will be used (with the collimator) when the variations are moderate; the uncovered aperture (with the mirror) when they are large, but not excessive; and, when the variations are very great, the box may be lifted altogether, so as to allow the entire range of azimuth.

* Not the individual fibre of the silk-worm, but the compound fibre in the state in which it is prepared for spinning.

† It is obvious that this step of the adjustment may precede the 1st and 2nd, where a saving of time is important.

come to rest, or nearly so, its deviation from the magnetic meridian is to be *estimated*, and the moveable arm of the torsion circle turned through the same angle in an opposite direction. The plane of detorsion then coincides, approximately, with the magnetic meridian.

4. The magnet is then to be substituted for the unmagnetic bar, and the telescope being directed towards the collimator, the point of the scale coinciding with the vertical wire is to be noted when the magnet is in the *direct* and *inverted* positions. Half the sum of these readings is the point of the scale corresponding to the magnetic axis of the magnet bar; and half their difference (converted into angular measure) is the deviation of the line of collimation of the telescope from the magnetic meridian. The telescope should be moved through this angle in the opposite direction.

5. In order to take out the remaining torsion of the thread, the magnet is again to be removed, and the unmagnetic bar (with its small magnet attached) substituted. The deviation of this bar from the magnetic meridian should then be read off on its divided scale, and the moveable arm of the torsion circle turned through a given angle in the opposite direction. The deviation being again read, a simple proportion will give the remaining angle of torsion; and the moveable arm being turned through this angle in the opposite direction, another observation will serve to verify the adjustment. The plane of detorsion then coincides with the magnetic meridian; and the magnet being replaced, the instrument is ready for use.

Observations.—The observations to be made with this instrument are, 1. of the *absolute declination*; 2. of the *variations of the declination*; and 3. of the *absolute intensity*.

For measurements of the *absolute declination* each observatory is furnished with an azimuth instrument. This instrument being placed in the magnetic meridian of the declination instrument, the point of the scale coinciding with the wire of the telescope is to be observed; the interval between this point and the point corresponding to the magnetic axis of the bar, converted into angular measure, is the deviation, D, of the line of collimation of the telescope from the magnetic meridian. The verniers of the horizontal circle being then read, the telescope is turned, and its wire made to bisect a distant mark, whose azimuth, Z, is known. If A denote the angle read off on the horizontal circle, it is manifest that the angle between the magnetic and the astronomical meridians is

$$A + Z + D,$$

Z and D being affected with their proper signs.

Some of the observatories are furnished with a transit instrument distinct from the theodolite; in others the transit instrument and theodolite are combined in one. In the former case the mark above referred to may be the central wire of the transit telescope, used as a collimator; so that for this case $Z = 0$. In the latter case, the angle Z is to be previously determined by the help of the transit instrument.

The division of the scale corresponding to the magnetic axis of the bar is to be considered as the *zero point*, and must be determined with great exactness. It is obvious that this point will be given by the mean of two readings of the scale, with the magnet in the *erect* and *inverted* positions, provided that care has been taken to eliminate the declination changes which may occur in the interval of the two parts of the observation. The obvious method of effecting this elimination is to determine the amount of the declination change, by means of an auxiliary apparatus, and to apply it as a correction to the second result. The same thing may, however, be effected by taking a *series of readings* of the declination instrument alone, with the bar alternately erect and inverted; the time chosen for observation being one in which the declination changes are small and regular, and the readings being made in as rapid succession as possible. By comparing each result with the *mean of the preceding and subsequent*, and then taking the mean of all these partial means, a very accurate determination may be made.

As an example of such a determination, we may take the following observation, made at the Dublin Magnetical Observatory, August 10, 1839. The first column of numbers contains the *actual* readings of the scale; the second the means of the preceding and subsequent readings; and the third the means derived from the combination of these last with the intermediate reading.

I. Reversed	157·0		
II. Direct ..	193·2		
Observations interrupted.			
III. Reversed	169·6		
IV. Direct ..	182·0	168·8	175·4
V. Reversed	168·0	182·3	175·2
VI. Direct ..	182·6	166·1	174·4
VII. Reversed	164·2		

Combining the three means in the last column with the number 175·1 deduced from I. and II., the final mean is 175·0.

The following observation, made at the Dublin Observatory, on the same day, will illustrate the preceding method of determining the absolute declination.

It must be premised that in this Observatory the transit telescope and the theodolite are distinct instruments. The centre of the theodolite is placed in the meridian line of the transit, and at the point where this line is cut by the magnetic meridian of the declination instrument; and the absolute declination is obtained by referring the telescope of the theodolite first to the line of collimation of the magnet, and then to that of the transit telescope.

It will be seen from the preceding table that the mean of the read-

ings III. V. VII., in the inverted position of the bar, which position in this instrument was the ordinary one, is 167·3; the mean time of observation being 1^h 40^m P. M., which corresponds nearly to the maximum declination of the day. But it has been already shown that the *zero point* of the scale is 175·0; and the difference, 7·7, multiplied into $43''\cdot22$ (the angle corresponding to a *single* division) gives, for the deviation of the line of collimation of the telescope from the *magnetic meridian*,

$$D = -5' \, 32''\cdot8.$$

The reading off on the limb of the theodolite was 150° 30′.

The telescope of the theodolite was then directed to the object-glass of the transit instrument, and its line of collimation brought into the *astronomical* meridian by making the image of the vertical wire coincide with that of the middle wire of the transit. The reading of the limb was then found to be 358° 15′ 50″, and subtracting 180° (the magnet being to the north, and the transit telescope to the south of the theodolite,) the *true north* corresponded to the angle 178° 15′ 50″ on the limb. The difference between this and the angle 150° 30′, corresponding to the *magnetic north*, is

$$A = 27^\circ \, 45' \, 50''.$$

Hence, as in this case Z = 0, the absolute declination is

$$A + D = 27^\circ \, 40' \, 17''\cdot2.$$

If, instead of the *actual* declination at any moment, we desired the *mean* declination of the day or of the month, we should employ (instead of the actual reading of the scale, 167·3) the corresponding mean result. We should thus obtain a new value of D, differing from the former by the amount of the declination change.

In the observatories about to be established by Her Majesty's Government and by the East India Company, the declination changes will be regularly observed with a *fixed telescope*, attached to a stone pillar, or to a firm pedestal of wood resting on solid masonry unconnected with the floor. Here then, instead of referring the telescope of the theodolite *directly* to the magnetic meridian by means of the moving collimator, the same result will be obtained, and probably in a better manner, by referring it to the line of collimation of the fixed telescope. For this purpose it is only necessary to employ this telescope as a collimator, the instrument being *reversed* in its Y supports, if necessary. This mode of observation has the advantage of connecting the absolute determination directly with the regular series of observations; and it is manifest that it is sufficient, without any other means, to determine whether any, and what changes may have occurred in the position of the fixed telescope.

2. In observing the *variations of the declination* the fixed telescope is alone employed. The observation consists simply in noting the point of the scale coinciding with the vertical wire, at three successive limits of the arc of vibration. The three readings being denoted

by a, b, c, the mean point of the scale corresponding to the time of the middle observation is

$$\tfrac{1}{4}(a + 2b + c).$$

This mode of observation is sufficient where the observer is not limited to a *precise moment* of observation. Otherwise the more exact method pointed out by Gauss is to be preferred*.

The changes of position of the scale may be converted into angular measure, the angle corresponding to one division being known. In general, however, this reduction will only be required in the monthly mean results.

Before the true changes of the declination can be deduced from the observed readings, it is necessary to apply a correction depending upon the force of torsion of the suspension thread. For supposing that the plane of detorsion has been brought (by the adjustments above described) to coincide with the mean magnetic meridian, it is manifest that on every deviation of the magnet from its mean position, the torsion force will be brought into play; and as this force tends to bring back the magnet to the mean position, the apparent deviations must be less than the true. The ratio of the torsion force to the magnetic directive force is experimentally determined by turning the moveable arm of the torsion circle through any given large angle (for example 90°), and observing the corresponding angle through which the magnet is deflected. Let u denote the latter angle, and w the former; then the ratio in question is

$$\frac{\mathrm{H}}{\mathrm{F}} = \frac{u}{w - u};$$

in which H is the coefficient of the torsion force, and F the moment arising from the action of the earth's magnetic force upon the free magnetism of the bar, the direction of the action being supposed to be perpendicular to its magnetic axis. The ratio of the two forces being thus found, the true declination changes are deduced from the apparent, by multiplying them by the coefficient

$$1 + \frac{\mathrm{H}}{\mathrm{F}}.$$

3. The experiments necessary to determine the *absolute intensity* of terrestrial magnetism are of two kinds,—experiments of *deflection* and experiments of *vibration*. The former of these give the *ratio* of the horizontal component of the earth's magnetic force to the moment of free magnetism of the deflecting bar; the latter determine the *product* of the same quantities.

Deflection.—The deflecting bar is to be placed at right angles to the magnetic meridian, and in the line drawn perpendicularly through the centre of the declination bar. Its centre is to be placed at

* See Taylor's Scientific Memoirs, vol. ii. part v. p. 44. *et seq.*

two different distances on this line; and in each position the observer is to note the angle of deflection produced by its action upon the suspended magnet of the declination instrument, the north end of the deflecting bar being placed, successively, towards the *east* and towards the *west*. Half the difference of the readings with the north end east and west, converted into angular measure, is the deflection sought. The experiments are then to be repeated on the *other side* of the suspended magnet, and at the *same distances*, so that each angle of deflection is the mean of four observed results.

Let r and r' denote the two distances, u and u' the corresponding angles of deflection. Also let X denote, as before, the horizontal part of the earth's magnetic force, and m the moment of free magnetism of the deflecting bar. Then the ratio of these quantities is given by the following formula:

$$\frac{m}{X} = \frac{r'^5 \tan u' - r^5 \tan u}{2\,(r'^2 - r^2)}.$$

The quantity so obtained is to be corrected for the torsion force of the suspension thread of the declination magnetometer; this is done by multiplying it by the number $1 + \frac{H}{F}$.

In choosing the distances of the deflecting bar, we should take as the smaller that which produces a deflection nearly amounting to the entire limit of the scale, provided it be not less than four times the length of the bar. The other should be greater than this in the ratio of $\sqrt{3}$ to 1, nearly. The distances themselves should be measured with great accuracy, and expressed in feet and decimals of a foot. For the purpose of this measurement, each observatory is furnished with a standard scale and a beam compass.

Vibration.—The declination bar being now removed, the deflecting bar is to be placed in a temporary stirrup of silk or wire, and so attached to the cylinder of the suspension thread. Its time of vibration is now to be determined with accuracy, from at least 100 oscillations. This may be done by placing a fine mark (as a piece of fine silver wire) on the front end of the bar, and noting the time of passage across the fixed wire of the reading telescope. The telescope is for this purpose furnished with an additional object lens, which is to be placed over the other, so as to adapt the instrument to near distances.

The time being observed, and the *moment of inertia* of the bar calculated, the *product* of the force of the earth and the moment of free magnetism of the bar is given by the formula

$$m\,X = \frac{\pi^2 K}{T^2};$$

in which π denotes the ratio of the circumference of a circle to its dia-

meter, K the moment of inertia, and T the time of vibration. The moment of inertia, K, is given by the formula

$$K = \frac{a^2 + b^2}{12} M;$$

a and b denoting the length and breadth of the bar, and M its *mass*.

In order to correct for the torsion force of the suspension thread, the time of vibration deduced from experiment must be multiplied by $\sqrt{1 + \frac{H}{F}}$; and therefore the *square of the time* by $1 + \frac{H}{F}$.

Again, inasmuch as these experiments necessarily occupy a considerable time, precision requires that we should apply a correction for the changes of the intensity which may occur in the course of the observation. In other words, we must reduce the observed value of mX (at the time of the experiment of vibration) to that which it had at the time of the experiment of deflection. This may at once be done by the aid of the horizontal force magnetometer, inasmuch as that instrument gives immediately the changes of mX. In this case, however,—that is, when there is a second magnet in the same room,—the deduced value of X will be (not the earth's magnetic force) but the resultant of that force and the force of the second magnet; and both experiment and calculation will be required to deduce the former. It is accordingly safer, perhaps, to remove the second magnet for the time to another apartment, and to determine the changes of the horizontal force by observing the time of vibration of this bar simultaneously with the two parts of the experiment above described. Thus, let t be the time of vibration during the experiment of deflection; t' the time during the experiment of vibration; then T′ being the observed time, the corrected time of the deflecting bar is

$$T = T' \frac{t}{t'}.$$

The values of $\frac{m}{X}$ and of mX being known, that of X is at once obtained by elimination. Let $\frac{m}{X} = A$, $mX = B$, then it is evident that

$$X = \sqrt{\frac{B}{A}}.$$

The number thus obtained for the force of the earth's magnetism expresses the ratio which that force bears to the *unit of force*,—the unit of force being that which, acting on the unit of *mass*, through the unit of *time*, generates in it the unit of *velocity*. These units are entirely arbitrary; but for the sake of convenience in comparison, it is desirable that they should be the same in all the observations which shall be made according to this system. For the unit of mass, then, we may take a *grain*; for the unit of time a *second*; and, if a *foot* be taken as the unit of space, the unit of velocity will be that of one foot per second.

As the magnetic force operates effectively only on the free or uncombined elements of the magnetic fluid, we are to understand by the earth's magnetic force, its action on the elementary unit of free magnetism; and we must take for that unit the quantity of free magnetism, which acting on another equal quantity at the unit of distance, exerts an effect equal to the unit of force already defined.

The following example, taken from Gauss's memoir, '*Intensitas vis Terrestris ad mensuram absolutam revocata,*' will serve to illustrate the preceding rules.

The experiments were made in two apparatuses, denoted by the letters A and B, and with three bars, distinguished by the numbers 1, 2, 3.

In the first place, the oscillations of bar 1 in the apparatus A, and of bar 2 in the apparatus B, were simultaneously observed. The time of a single oscillation, reduced to infinitely small arcs, was found to be

for bar 1 ...... $15^{s}\cdot22450$,
for bar 2 ...... $17\cdot29995$;

the former being deduced from 305 oscillations, the latter from 264. The times were observed with a chronometer, whose daily rate was $-14^{s}\cdot24$.

Bar 3 being then suspended in the apparatus A, bar 1 was placed in the right line perpendicular to the magnetic meridian, both on the east and west side of the suspended bar (and in both cases with the north end east and west successively), and the deflection of bar 3 was observed in each position of bar 1. These experiments were repeated for two different distances, r, and with the following values of the deflection, u:

$$r = 1\cdot2 \text{ metres}, \quad u = 3^{\circ}\,42'\,19''\cdot4;$$
$$r' = 1\cdot6 \quad ,, \quad u' = 1\;\;34\;\;19\cdot3.$$

During these experiments the oscillations of bar 2 were observed in the apparatus B. The time of a single oscillation, deduced from 414 oscillations, and corresponding to the mean time of the experiments of deflection, was $17^{s}\cdot29484$.

The values of $\frac{H}{F}$, for bars 1 and 3, were found to be $\frac{1}{597\cdot4}$ and $\frac{1}{721\cdot6}$ respectively. The moment of inertia of bar 1 was

$$K = 4328732400,$$

taking a *millimetre* and a *milligramme* as the units of distance and mass.

Now, to calculate the results of these experiments:—the inequality of the times of oscillation of bar 2 proves that a slight variation of the terrestrial magnetic intensity had taken place in the interval of the two parts of the observation. Accordingly, we have to reduce the observed time of oscillation of bar 1, to that corresponding to the mean state of the magnetic intensity during the second part of the observation. This time requires also a second reduction for the

chronometer's rate, and a third for the torsion of the thread. The reduced time is thus

$$T = 15{\cdot}22450 \times \frac{17{\cdot}29484}{17{\cdot}29995} \times \frac{86400}{86385{\cdot}76} \times \sqrt{\frac{598{\cdot}4}{597{\cdot}4}} = 15{\cdot}23580.$$

$$\therefore mX = \frac{\pi^2 K}{T^2} = 179770600 = B.$$

From the observed deflections we obtain

$$\frac{m}{X} = \frac{r'^5 \tan u' - r^5 \tan u}{2\,(r'^2 - r^2)} = 56528100;$$

the millimetre being taken as the unit of distance; and correcting this quantity for the torsion of the thread, by multiplying it by the coefficient $1 + \frac{H}{F}\left(= \frac{722{\cdot}6}{721{\cdot}6}\right)$,

$$\frac{m}{X} = 56606437 = A.$$

Accordingly,

$$X = \sqrt{\frac{B}{A}} = \sqrt{\frac{179770600}{56606437}} = 1{\cdot}782088.$$

The following Table contains the arc values of one division of the scale in each instrument, expressed in decimals of a minute.

TABLE I.

Designation of Instrument.	Observatory.	Arc value of one division.
I.	H.M.S. Erebus	0·7267
II.	Van Diemen's Land	0·7085
III.	Montreal..........	0·7208
IV.	Cape of Good Hope	0·7525
V.	St. Helena	0·7108
A.	Simla	0·6760
B.	Madras	0·6746
C.	Singapore	0·6786
H.	H.M.S. Terror	0·6786

HORIZONTAL FORCE MAGNETOMETER.

The instrument employed in determining the horizontal component of the earth's magnetic force is similar, in principle, to the "*bifilar magnetometer*" of M. Gauss. It is a magnet bar, suspended

by two equidistant wires, or (more accurately) by two portions of the same wire, the distance of whose bearing points is the same above and below; by the rotation of the upper extremities of the wire round their middle point, the magnet is maintained in a position at right angles to the magnetic meridian.

It is manifest from the nature of this suspension, that the *weight* of the suspended body will tend to bring it into the position in which the two portions of the wire are in the *same plane* throughout. The moment of the directive force is G sin v;—v denoting the angle formed by the lines joining the bearing points above and below, or the deviation from the plane of detorsion; and G being expressed by the formula

$$G = W\frac{a^2}{l};$$

in which W denotes the weight of the suspended body, a half the interval of the wires, and l their length. The earth's magnetic force, on the other hand, tends to bring the magnetic axis of the bar into the magnetic meridian, with the force F sin u; in which u is the deviation of the magnetic axis from the meridian, and F is the product of the horizontal part of the earth's magnetic force into the moment of free magnetism of the bar. The magnet being thus acted on by two forces, will rest in the position in which their moments are equal. When the instrument is so adjusted that $u = 90°$, or the magnet at right angles to the magnetic meridian,

$$F = G \sin v;$$

and the ratio of the forces is known, when we know the angle v. But as one of these forces is constant, and the other variable, it is evident that the place of the magnet will vary around its mean position, and that the variations of angle are connected with the variations of the force. This connexion is expressed by the formula

$$\frac{\Delta F}{F} = -\operatorname{cotan} v \, \Delta u;$$

the angle Δu being expressed in parts of radius.

Construction.—The magnet bar is of the same dimensions as that of the declination instrument. The collimator, by which its changes of position are observed, is attached to the stirrup, and has a motion in azimuth *. The suspending wire passes round a small grooved wheel, on the axis of which the stirrup rests by inverted Y's; and the instrument is furnished with a series of such wheels, whose diameters increase in arithmetical progression, (the common difference being about $\frac{1}{20}$th of an inch,) for the purpose of varying the interval of the wires. The exact intervals, corresponding to each separate

* The horizontal force magnetometers belonging to H. M. ships Erebus and Terror are provided with a *mirror* attached to the stirrup of the magnet, and *two scales*, similar to those of the declination magnetometer. The mirror has a movement in azimuth, in the same manner as the collimator which it replaces.

wheel, have been determined by the artist by accurate micrometrical measurements; they are given in Tables III. and IV. in p. 30. The same interval is altered, at the upper extremity, by means of two screws (one right-handed and the other left-handed) cut in the same cylinder; the wires being lodged in the intervals of the threads, and their distance regulated by a micrometer head. The interval of the threads of this screw (which is precisely the same for all the instruments) is $\frac{2}{77}$ths, or ·02597 of an inch. The micrometer head is divided into 100 parts; and, as one revolution of the head corresponds to *two* threads of the screw, a single division is equivalent to ·0005194, or the $\frac{1}{2000}$th of an inch nearly. The micrometer head has been carefully adjusted by the artist, so that the index is at zero, when the interval of the wires is exactly half an inch.

The collimator, in this instrument, is inclosed in a light tube attached to the stirrup. The aperture of the lens is about $\frac{8}{10}$ths of an inch, and its focal length about 8 inches. The divisions of the scale are the same as in the collimator of the declination magnetometer; the corresponding arc values have been ascertained for each instrument by accurate experiment, and are given in Table II. p. 30.

The larger parts of this apparatus,—the box, the framework, and the support,—are precisely similar to those of the declination magnetometer. In addition to the parts already described, the instrument is furnished with a spare magnet; a brass weight, required in determining the plane of detorsion of the wires relatively to the magnetic meridian; a thermometer, the bulb of which is within the box, for the purpose of ascertaining the interior temperature; and a copper ring used in checking the vibrations.

Adjustments.—The instrument being placed on its support, the base is to be levelled, and the whole apparatus fixed. Having then selected one of the small grooved wheels, and fixed it, temporarily, with its axis horizontal, the wire is to be passed round it; and the free extremities of the wire being passed through the corresponding holes in the suspension roller, placed beneath, weights are to be attached, and the two portions of the wire allowed to assume their natural position; the extremities may then be *fastened* to the roller, by introducing small wooden plugs in the holes. The parts are then to be inverted, and put in their proper places; the suspension apparatus resting on the divided circle, and the wire hanging down the tube.

The collimator (its scale having been previously adjusted to focus*) is to be screwed on to the stirrup, and the latter attached to the axis of the grooved wheel by means of its Y's. The magnet is then introduced into the stirrup, and levelled; and the wires wound upon the roller, until the collimator is at the desired height.

These preparations being made, the adjustments are the following:

1. Determine experimentally the angle through which it is necessary to turn the moveable arm of the torsion circle, in order to deflect the magnet from the magnetic meridian to a position at right angles

* This adjustment has been already made by the artist.

to it, the two positions being merely *estimated*. The cosine of this angle is, approximately, the ratio of the magnetic force to the torsion force, or the value of the fraction $\frac{F}{G}$. The nearer this ratio is to unity, the more delicate will be the instrument; practically, $\frac{9}{10}$ will be found a convenient value. If, on making the foregoing experiment, the ratio should be found to fall below, or to exceed the proper limits, the torsion force must be altered by introducing a different wheel, and making the corresponding alteration in the interval of the upper extremities of the wires.

2. The magnetic axis being brought, approximately, into the magnetic meridian, by turning the moveable arm of the torsion circle, the collimator is to be turned, by its independent motion, until some point about the middle of the scale coincides with the vertical wire of the fixed telescope. This point of the scale is to be noted in the usual manner.

3. The magnet is then to be removed, and the brass weight attached. Note the new point of the scale which coincides with the wire of the telescope. Then, if the magnet had been placed (in the previous experiment) in its *direct* position (i. e. north to north) the error of the plane of detorsion is

$$\left(\frac{G}{F}+1\right)v',$$

v' being the difference of the two readings, converted into angular measure. If, on the other hand, the magnet had been *reversed* (i. e. north end to south) the error is

$$\left(\frac{G}{F}-1\right)v''$$

The moveable arm of the torsion circle is then to be turned through this angle, in the opposite direction; and the magnetic axis will be in the magnetic meridian.

The difference of the two readings, corresponding to a given error, being much greater in the reversed than in the direct position of the magnet, it follows that the former affords a much more delicate method of making the desired adjustment.

4. The brass weight remaining attached, turn the moveable arm of the torsion circle through 90°. Then turn back the collimator, until some point about the middle of the scale coincides with the vertical wire of the fixed telescope; and note the reading.

5. Now remove the brass weight, and replace the magnet. The magnetic force of the earth will bring it back towards the magnetic meridian, and the scale will be thrown out of the field of the telescope. Then turn the moveable arm of the torsion circle, until the point of the scale last noted is brought to coincide again with the wire of the telescope; the magnetic axis is then in the plane perpendicular to the magnetic meridian, and the adjustment is complete.

The following adjustment, made at the Dublin Magnetical Observatory, will serve to exemplify the foregoing description.

August 14.—Having attached the wire in the manner described, the wheel No. 5, whose diameter $= 0{\cdot}4607$ of an inch, was introduced, and the stirrup and weight appended. The upper extremities of the wire having been adjusted to the interval of *half an inch* (the zero point) by means of the micrometer, the correction to be made in the upper interval was, in parts of an inch,

$$0{\cdot}4607 - 0{\cdot}5000 = -0{\cdot}0393;$$

and dividing this number by $\cdot 0005194$, the fraction of an inch corresponding to a *single division* of the micrometer head, the resulting number, 76, expresses the *number of divisions* through which the micrometer head was to be turned *backward*, so as to equalize the interval of the wires at top and bottom. The micrometer was accordingly turned back from 100 (or zero) to the division numbered 24.

1. The magnet being now introduced into the stirrup, and the weight removed, it was found necessary to turn the moveable arm of the torsion circle through $151^\circ\ 30'$, in order to deflect the magnet from the magnetic meridian to a position at right angles to it, the two positions being known only approximately. Hence the approximate value of the ratio of the forces was

$$\frac{F}{G} = \cos\left(151^\circ\ 30'\right) = \cdot 88.$$

2. The moveable arm of the torsion circle was then turned, until the magnetic axis was, approximately, in the magnetic meridian: and the reading of the torsion circle was found to be $260^\circ\ 10'$. The collimator was then turned, by its independent motion, until the division coinciding with the vertical wire of the fixed telescope was about the middle of the scale. The coinciding division was 140.

3. The magnet was now removed, and the brass weight attached; and the new coinciding division was observed to be 118. The difference of the two readings is 22, and multiplying $1'{\cdot}0776$ (the arc value of a single division) by this difference, the angle $v' = 24'$. Consequently (the magnet having been placed in the *direct* position) the error of the plane of detorsion was

$$\left(\frac{G}{F} + 1\right) v' = 24' \times \frac{1{\cdot}88}{0{\cdot}88} = 51'.$$

Subsequent trials, however, showed that the error here deduced was greater than the truth; and that the two readings of the scale agreed, when the reading of the torsion circle was $260^\circ\ 32'$.

4. The brass weight being attached, the moveable arm of the torsion circle was turned through 90 degrees, so that its reading was $350^\circ\ 32'$. The collimator was then turned back, by its independent motion, until the coinciding division was about the middle of the scale. The reading of the scale was 134.

5. The brass weight was then removed, and the magnet replaced; the scale was consequently thrown out of the field of the telescope. The moveable arm of the torsion circle was turned further, in the same direction as before, until the division of the scale last noted,

134, again coincided with the wire of the telescope. The magnetic axis was then perpendicular to the magnetic meridian, and the adjustment was complete.

The reading of the torsion circle, after this step of the adjustment, was found to be 51° 2′; and consequently

$$v = 60° \, 30', \text{ and } \frac{F}{G} = \sin v = \cdot 8704.$$

Observations.—The observations to be made with this instrument are those of the *absolute* value of the *horizontal intensity*, and its *changes*.

From the explanation of the principle of the instrument, given above, it is manifest that it will serve to determine the moment of the force exerted by the earth upon the free magnetism of the suspended bar. Let X denote (as before) the horizontal part of the earth's magnetic force; m the moment of free magnetism of the bar; then

$$m \, X = F,$$

F having the same meaning as before (page 24). Hence, substituting the values of F and G, we have

$$m \, X = W \frac{a^2}{l} \sin v;$$

in which equation all the quantities of the second member may be obtained by direct measurement. The chief difficulty in this method consists in the determination of the quantity a, which should be known to a very small fractional part of its actual value. This difficulty has been overcome by the measuring apparatus connected with the suspension, which (as has been already stated) serves to determine the interval of the wires, at their upper extremity, to the $\frac{1}{2000}$th of an inch. The numbers given in Tables III. and IV. (p. 30) for the lower interval, may be relied on to the same degree of accuracy. It is scarcely necessary to mention that the length of the wires, l, is to be measured between the points of contact above and below.

The *product* of the earth's magnetic force into the magnetic moment of the bar being thus known, the *ratio* of the same quantities is to be determined by removing the bar from its stirrup, and using it to *deflect* the suspended bar of the declination instrument, according to the known method devised by Gauss. The experiments of deflection may, however, be performed without the aid of the second magnetometer, by operating upon another bar placed in the *reverse* position. This method has even the advantage in point of delicacy; but it labours under the disadvantage of requiring that the value of $\frac{F}{G}$ should be determined for the second bar.

The chief use of this apparatus is in observing the *variations* of the intensity. In these observations it is only necessary to note, at any moment, the point of the scale coinciding with the vertical wire of the fixed telescope, the mode of observing being precisely the

same as in the other instrument. Let n be the number of divisions, and parts of a division, by which the reading at any moment differs from its mean value; then the corresponding variation of the angle (in parts of radius) is

$$\Delta u = n a;$$

a denoting the arc value (in parts of radius) corresponding to a single division. Substituting this in the formula of page 24, and making

$$k = a \operatorname{cotan} v,$$

we have

$$\frac{\Delta F}{F} = -k n.$$

The values of a have been determined for each of the instruments and are given in Table II. p. 30.

Thus, in the instrument in use in the Dublin Observatory, the angle corresponding to a single division of the scale $= 1'{\cdot}0776$, so that $a = {\cdot}0003135$. And since, in the adjustment of this instrument it was found that $v = 60^\circ\, 30'$, we have

$$k = {\cdot}0003135 \times \operatorname{cotan}(60^\circ\, 30') = {\cdot}0001774.$$

The quantity F, in the preceding formula, is the product of the earth's magnetic force into the moment of free magnetism of the bar; and, as the latter quantity varies with the temperature, it is necessary to apply a correction, before we can infer the true changes of the earth's force. This correction is easily deduced. Since $F = X m$, there is

$$\frac{\Delta F}{F} = \frac{\Delta X}{X} + \frac{\Delta m}{m};$$

so that the correction required is $-\frac{\Delta m}{m}$. Let t denote the temperature, in degrees of Fahrenheit; q the relative change of the magnetic moment corresponding to one degree; then

$$-\frac{\Delta m}{m} = q\,(t - 32).$$

Accordingly, the changes of the earth's force will be expressed by the formula

$$\frac{\Delta X}{X} = -k n + q\,(t - 32).$$

It is not necessary that these reductions should be applied to the individual results, except in cases of marked change, where it is desired to trace the progress of the actual phenomena. The results should be recorded as they are observed, in parts of the scale; and the reductions made in the monthly, or other mean values.

The following Table contains the arc values of one division of the scale, in each instrument, expressed in *decimals of a minute*; as also

the same quantities reduced to *radius*, as the unit, by multiplying by the number ·0002909.

TABLE II.

Designation of Instrument.	Observatory.	Arc values of one division.	
		In Minutes.	In parts of Radius.
I.	H.M.S. Erebus	1·075	·0003127
II.	Van Diemen's Land	1·080	·0003142
III.	Montreal..........	1·074	·0003124
IV.	Cape of Good Hope	1·084	·0003153
V.	St. Helena	1·080	·0003142
A.	Simla	1·086	·0003159
B.	Madras	1·079	·0003139
C.	Singapore	1·078	·0003136
H.	H.M.S Terror	1·076	·0003131

The following Tables contain the intervals of the axes of the wires corresponding to each wheel, in decimals of an inch; the wire used being that designated in commerce as "silver, fine 6."

TABLE III.

No. of Wheel.	I. H.M.S. Erebus.	II. Van Diemen's Land.	III. Montreal.	IV. Cape of Good Hope.	V. St. Helena.
1	·2536	·2549	·2529	·2542	·2536
2	·3032	·3058	·3055	·3055	·3065
3	·3529	·3516	·35[illegible]9	·3497	·3513
4	·4058	·4088	·4078	·4052	·4071
5	·4562	·4555	·4581	·4555	·4545
6	·5055	·5071	·5042	·5055	·5058
7	·5555	·5604	·5588	·5565	·5591
8	·6071	·6071	·6071	·6097	·6081

TABLE IV.

No. of Wheel.	A. Simla.	B. Madras.	C. Singapore.	H. H.M.S. Terror.
7	·3614	·3643	·3598	·3637
8	·4153	·4159	·4124	·4146
9	·4620	·4643	·4663	·4640
10	·5182	·5146	·5182	·5156
11	·5663	·5659	·5666	·5672
12	·6153	·6111	·6120	·6143

VERTICAL FORCE MAGNETOMETER.

The instrument used in determining the changes of the *vertical component* of the magnetic force is a magnetic needle resting on agate planes, by knife-edges, and brought to the horizontal position by weights. From the changes of position of such a needle, the changes of the vertical force may be inferred, when we know the *mean inclination* at the place of observation, and the times of vibration of the needle in the vertical and in the horizontal planes. For it may be shown that

$$\frac{\Delta F}{F} = \frac{T'^2}{T^2} \cot \theta \, \Delta \eta \, ;$$

where $\Delta \eta$ denotes the change of the angle in parts of radius, θ the *inclination*, and T and T′ the times of vibration of the needle in the *vertical* and *horizontal* planes respectively.

Construction.—The magnetic needle is 12 inches in length. It has a cross of wires at each extremity, attached by means of a small ring of copper; the interval of the crosses being 13 inches. The axis of the needle is formed into a *knife edge*, the edge being adjusted to pass as nearly as possible through the centre of gravity of the unloaded instrument. The weights by which the other adjustments are effected are small brass screws moving in fixed nuts, one on each arm; the axis of one of the screws being *parallel* to the magnetic axis of the needle, and that of the other *perpendicular* to it.

The agate planes upon which the needle rests are attached to a solid support of copper, which is firmly fixed to a massive marble base. In this support there is a provision for raising the needle off the planes, the contrivance for effecting this object being similar to that employed in the inclination instrument. The whole is covered with an oblong box of mahogany, in one side of which are two small glazed apertures, for the purpose of reading; the opposite side of the box is covered with plate glass. A thermometer, within the box, shows the temperature of the interior air; and a spirit level, attached to the marble base, serves to indicate any change of level which may occur in the instrument.

The position of the needle at any instant is observed by means of two micrometer microscopes, one opposite each end. These microscopes are supported on short pillars of copper, attached to the base of the instrument. They are so adjusted that one complete revolution of the micrometer screw corresponds to about 5 minutes of arc. The micrometer head is divided into 50 parts; and, consequently, the arc corresponding to a single division is about 0′·1.

In addition to these parts, the apparatus is provided with a brass bar of the same length as the magnet, (furnished, like it, with cross wires at the extremities, and knife-edge bearings,) for the purpose of determining the zero points of the micrometers; a brass scale, divided to 10′, used in ascertaining the value of the micrometer divisions; and a horizontal needle, to be employed in determining the azimuth of the vertical plane in which the needle moves.

Adjustments.—The following are the adjustments required in this instrument:

1. The instrument being placed on its support, in a suitable position with respect to the other two instruments, the azimuth of the plane in which the needle is to move may be adjusted in the following manner. The plane is made to coincide, in the first instance, with the magnetic meridian, by means of the horizontal needle which moves upon a pivot fixed to the top of the scale. A small theodolite (or other instrument for measuring horizontal angles) is then placed on the base; and its telescope brought to bear on a distant mark. The telescope should then be moved through a horizontal angle equal to the intended azimuth of the instrument, but in an opposite direction. The base of the instrument is next to be turned, without disturbing the theodolite, until the mark is again bisected by the wire of the telescope: it is then in the required azimuth. The base should then be levelled, and permanently fixed.

2. The *fixed* wires of the microscopes are then to be adjusted to the same *horizontal* line. This is effected by means of the brass needle. This needle being placed upon the agate planes, by its knife-edges, and allowed to come to rest, it is manifest that the line joining the cross wires will be horizontal, provided it be perpendicular to the line joining the centre of gravity and the axis. To effect this latter adjustment, the needle (a great part of whose weight is disposed below the knife-edge) is furnished also with a small moveable weight. The test of the adjustment is similar to that of the corresponding adjustment of the ordinary balance. The moveable wire of one of the microscopes being brought to bisect the cross, if the adjustment is complete, it will bisect the cross at the other extremity upon reversal; if not, the position of the needle will indicate in what manner the weight is to be moved.

A horizontal line being thus obtained, the fixed wires of the microscopes are to be adjusted to it, by moving the capstan-headed screws with which they are connected.

3. The last adjustment is that of the magnetic needle to the horizontal position. To effect this adjustment the needle is furnished with two moving weights, one on each arm. These weights (it has been already stated) are screws moving in fixed nuts, one in a direction parallel to the magnetic axis of the needle, and the other in a direction at right angles to it. By the movement of the former the needle is brought to the horizontal position; and by that of the latter, the centre of gravity is made to approach the centre of motion, and the sensibility of the instrument thereby augmented.

It is manifest that the line joining the two crosses at the end of the needle will, in general, deviate from the magnetic axis. The amount of this deviation may be ascertained (before the instrument is permanently fixed) by reversing the needle on its supports, the plane of the instrument being *perpendicular to the magnetic meridian.* Half the difference of the readings, in the two positions, will be the deviation sought.

Observations.—In observing the variations of the vertical force

with this instrument, it is only necessary to bring the moveable wire of each micrometer to bisect the opposition cross of the needle. The interval between the fixed and moveable wires, expressed in angular measure, is the deviation of the needle from the horizontal position; and the changes of the vertical force are thence obtained by multiplying by a constant coefficient.

If n denote the number of divisions, of the micrometer head, corresponding to the interval of the wires,

$$\Delta \eta = n\, a,$$

a denoting the angle (in parts of radius) corresponding to a single division. Consequently, the changes of the force are expressed (as in the case of the other component) by the formula

$$\frac{\Delta \mathrm{F}}{\mathrm{F}} = k\, n\,;$$

in which the constant coefficient is

$$k = a \operatorname{cotan} \theta \,.\, \frac{\mathrm{T}'^2}{\mathrm{T}^2}.$$

The quantity F in the preceding formula is the product of the vertical component of the earth's magnetic force multiplied by the moment of free magnetism of the needle; or

$$\mathrm{F} = m\, \mathrm{Y}.$$

accordingly the results thus deduced require a correction for the effects of temperature upon the quantity m. This correction is similar to that applied to the horizontal intensity, and the corrected expression of the changes of the vertical component is consequently

$$\frac{\Delta \mathrm{Y}}{\mathrm{Y}} = k\, n + q\,(t - 32)\,;$$

where t denotes the actual temperature (in degrees of Fahrenheit) at the time of observation, and q the relative change of the magnetic moment of the needle corresponding to one degree. As in the case of the other instruments, however, it is not in general necessary to apply these reductions to the individual results.

TIMES OF OBSERVATION.

The objects of inquiry in Terrestrial Magnetism may be naturally classed under two heads, according as they relate, 1. to the *absolute* values of the magnetic elements at a given epoch, or their *mean* values for a given period; or 2. to the *variations* which these elements undergo from one epoch to another. It will be convenient to consider separately the observations relating to these two branches of the subject.

Absolute Determinations.

By the method of observation which has been suggested for the *absolute declination*, every determination of the position of the declination bar is rendered absolute. We have only to consider the varying angle between the magnetic axis of the bar and the line of collimation of the fixed telescope, as a correction to be applied to the

constant angle (already determined) between the latter line and the meridian. It is manifest that if the *fixity* of the line of collimation of the telescope could be depended on, a single determination of the latter angle would be sufficient. But this is not to be trusted for any considerable period; and it will be therefore necessary, from time to time, to refer the line of collimation of the telescope to the meridian, in the manner already explained. This observation may be repeated *once a month*, or more frequently if any change in the position of the telescope be suspected.

In the case of the *intensity*, there is another source of error (beside that due to a change in the position of the instruments) which can only be guarded against by a repetition of *absolute* measurements. The magnetic moment of the magnet itself may alter; and the observations of intensity changes afford no means of separating this portion of the effect from that due to a change in the earth's magnetism. This separation can only be effected by means analogous to those employed in the determination of the absolute value of the horizontal intensity; and accordingly one or other (or both) of the methods proposed for this determination should be occasionally resorted to. It is desirable that this observation should be repeated *once in every month*; and more frequently, whenever the changes observed with the horizontal force magnetometer indicate, by their *progressive* character, a change in the magnetic moment of the suspended bar.

It would be easy, in theory, to devise a method by which the vertical force magnetometer might be made to serve in determining the absolute value of the vertical intensity. The means which at present offer themselves appear, however, to be surrounded with practical difficulties; and it seems safer to deduce this result *indirectly*. From the formulæ given in page 13, we have

$$Y = X \tan \theta;$$

so that if the inclination, θ, be known, and the horizontal intensity, X, determined in absolute measure, the vertical intensity, Y, is inferred.

For the purpose of observing the element θ, each observatory is furnished with an inclination instrument. The observation should be made in an open space, sufficiently remote from the magnets of the observatory, and from other disturbing influences; and a series of measures should be taken *simultaneously* with the two intensity magnetometers, for the purpose of eliminating the *changes of the inclination* which may occur in the course of the observation. As to the mode of observation, the best seems to be the usual one, the plane of the circle coinciding with the magnetic meridian; but for the purpose of testing the axles of the needles, and the limb of the instrument, it is desirable that a series of observations should be made in *various azimuths*,—for example, every 30° of the azimuth circle commencing with the magnetic meridian. The inclination is then inferred, from each pair of corresponding results, by the formula

$$\cot^2 \theta = \cot^2 \eta + \cot^2 \eta';$$

η and η' being the observed angles of inclination in two planes at right

angles to one another. Where the inclination is great (as in Canada), this method will serve to test only a limited portion of the circumference of the axle and limb. In this case the best course appears to be that pointed out by Major Sabine*, namely, to convert one of the needles, temporarily, into a needle on Mayer's principle, by loading it with sealing-wax; and to deduce the inclination, from the angles of position of the loaded needle, by the known formula of Mayer. The observations here suggested having been very carefully made, and the inclination changes eliminated in the manner above explained, the observed difference between the *mean* and the result obtained in the *magnetic meridian*, should be applied as a correction for the errors of axle and limb to all future observations made in the meridian.

These observations should be made at the same periods as those of the absolute horizontal intensity.

Variation of the Elements.

The *variations* of the magnetic elements are, 1. Those variations whose amount is a function of the *hour angle* of the sun, or of his *longitude*; and which return to their original values at the same hour in successive days, or the same season in successive years. These, from their analogy to the corresponding planetary inequalities, may be denominated *periodical*. 2. The variations, which are either continually *progressive*, or else return to their former values in long and unknown periods; these may in like manner be denominated *secular*. 3. The *irregular* variations, whose amount changes from one moment to another, and which observe (apparently) no law.

The *periodical* variations (with the exception of those of the *declination*) have hitherto been little studied; and, even in the case of the single element just mentioned, the results have scarcely gone beyond a general indication of the hours of maxima and minima, and of the changes of their amount with the season. The subject is nevertheless of the highest importance in a theoretical point of view. The phenomena depend, it is manifest, on the action of solar heat, operating probably through the medium of thermo-electric currents induced on the earth's surface. Beyond this rude guess, however, nothing is as yet known of the physical cause. It is even still a matter of speculation whether the solar influence be a *principal*, or only a *subordinate* cause, in the phenomena of terrestrial magnetism. In the former case, the periodical changes are to be regarded as the effect only of the *variations* of that influence; in the latter, they must be considered as its entire result, the action in this case only serving to modify the phenomena due to some more potent cause. It may be fairly hoped that a diligent study of this class of phenomena will not only illustrate this and other doubtful points in the physical foundation of the science; but also, whenever that physical cause shall come to be fully known, and be made the basis of a mathematical theory, the results obtained will serve to give to the latter a numerical expression, and to test its truth. Even

* Reports of the British Association, vol. vii. p. 55.

the knowledge of the empirical laws of the hourly and monthly fluctuations must prove a considerable accession to science; and (as one of its more obvious applications) will enable the observer to reduce his results, as far as this class of changes is concerned, to their *mean* values.

For the complete determination of the hourly and monthly changes of the magnetic elements, a persevering and laborious system of observation is requisite. The *irregular* changes are so frequent, and often so considerable, as (partially at least) to mask the regular; and the observations must be long continued at the same hours, before we can be assured that the irregularities do not sensibly affect the mean results. Again, in a theoretical point of view, the nocturnal branch of the curves by which the periodical changes are represented is quite as important as the diurnal; and it is manifest that nothing can be done towards its determination without the cooperation of a number of observers. At each of the Observatories about to be founded by Her Majesty's Government and by the East India Company, there will be three assistant observers placed under the command of the Director; and it is intended that the observations shall be taken *every two hours* throughout the twenty-four. In order that this series of observations, which is especially destined for the determination of the periodical changes, may at the same time cast some light upon the irregular movements, it is proposed that they shall be *simultaneous* at all the observatories. The hours which have been agreed upon are the *even* hours (0, 2, 4, 6, &c.) *Göttingen mean time.* It is likewise intended that *one* observation of the twelve shall be a *triple* observation, the position of the magnets being noted according to an arrangement which will be hereafter explained. The time of this triple observation will be 2 P.M., Göttingen mean time.

The barometer, and the wet and dry thermometers, will be registered at each of the twelve magnetic hours.

No observation will be taken on Sunday.

No distinct series of observations is required for the determination of the *secular* variations. In the case of the *declination*, the yearly change will be obtained by a comparison of the monthly mean results (for the *same month* and *same hour*) in successive years. The observations of two years only will thus furnish 144 separate results, from which both the periodical and the irregular changes are eliminated; so that great precision may be expected in the final result, notwithstanding the limited period of observation. The same mode of reduction will apply to the two components of the *intensity*, provided that no change shall have taken place in the magnetic moment of the bars employed. In the latter event, recourse must be had to the *absolute* determinations for a knowledge of the secular changes.

The subject of the *irregular* movements has acquired a prominent, and almost absorbing interest, from the recent discoveries of Gauss. It has been ascertained that the resultant direction of the forces, by which the horizontal needle is actuated at a given place, is *incessantly* varying, the oscillations being sometimes small, sometimes very con-

siderable;—that similar fluctuations occur at the most distant parts of the earth's surface, at which corresponding observations have been as yet made;—and that the instant of their occurrence is the same everywhere. The intensity of the horizontal force has been found subject to analogous perturbations.

For the full elucidation of the laws of these interesting phenomena, it is of the first importance that the stations of observation should be separated as widely as possible over the earth's surface, and that their positions should be chosen near the points of maxima and minima of the magnetic elements. This has been in a great measure accomplished as regards the observatories about to be founded by Her Majesty's Government and by the East India Company. The stations are wide asunder in geographical position, and they are in the neighbourhood of points of prominent interest in reference to the isodynamic and isoclinal lines. The results of observation at these stations will soon testify whether the shocks to which the magnetic needle is subject, are of a local or of a universal character as regards the globe; and in either event we may expect that they will furnish information of great value (in reference to a physical cause) as to the magnitude of the phenomena in different places, and the elements on which it depends.

In the observations destined to illustrate this class of phenomena, it is proposed to follow the plan laid down by Gauss, as nearly as the proposed extension of that plan will permit. The Göttingen terms* will be observed as agreed on by the German Magnetic Association; but in place of confining them to four in the year, as at present, they will be extended to twelve.

The four *terms* at present agreed upon by the German Magnetic Association occur in the months of February, May, August, and November, and commence on the *Friday preceding the last Saturday* of the month, at 10 P.M. *Göttingen mean time*. It is proposed that the eight additional terms shall be held on the *Wednesday nearest the* 21*st* of the eight remaining months; the hour of commencement being the same as before. Thus, in the course of the next three years, there will be thirty-six terms of simultaneous observation. The days of commencement of these terms are given in the subjoined table. The hour of commencement will be, in all cases, 10 P.M. *Göttingen mean time*.

In these terms the declination magnetometer will be observed at intervals of *five minutes*, the corresponding moments of observation being the *full* minutes, 0, 5, 10, 15, &c. Göttingen mean time. Each of the force magnetometers will be observed at intervals of *ten minutes*; the epochs of observation of the horizontal force magnetometer being $2^m\ 30^s$, $12^m\ 30^s$, $22^m\ 30^s$, &c., and those of the vertical force magnetometer $7^m\ 30^s$, $17^m\ 30^s$, $27^m\ 30^s$, &c. Göttingen mean time. By this arrangement an observation will be taken every $2\frac{1}{2}$ minutes, and the observer will have sufficient time between the observations to transfer his attention from one instrument to the next without embarrassment or confusion.

* For the details of the arrangements of the "*term observations*," see the translation of Gauss's memoir in Taylor's Scientific Memoirs, vol. ii. part v.

Days of commencement of the terms of simultaneous observation, during the years 1840, 1841, and 1842.

Month.	1840.	1841.	1842.
January	Wednesday 22	Wednesday 20	Wednesday 19
February	Friday 28	Friday 26	Friday 25
March	Wednesday 18	Wednesday 24	Wednesday 23
April	Wednesday 22	Wednesday 21	Wednesday 20
May.........	Friday 29	Friday 28	Friday 27
June.........	Wednesday 24	Wednesday 23	Wednesday 22
July.........	Wednesday 22	Wednesday 21	Wednesday 20
August.	Friday 28	Friday 27	Friday 26
September ...	Wednesday 23	Wednesday 22	Wednesday 21
October	Wednesday 21	Wednesday 20	Wednesday 19
November ...	Friday 27	Friday 26	Friday 25
December....	Wednesday 23	Wednesday 22	Wednesday 21

In case of the occurrence of Auroras, the hourly should at once be exchanged for uninterrupted observation, should that not be actually in operation. The affections of the magnetometers during thunder-storms, if any, should be noticed, though it is at present believed that they have no influence.

During an earthquake in Siberia in 1829, the direction of the horizontal needle, carefully watched by M. Erman, was uninfluenced; should a similar opportunity occur, and circumstances permit, it should not be neglected.

2. FIGURE OF THE EARTH.

If the traveller be provided with invariable pendulums, with all the necessary apparatus for determining the length of the seconds pendulum, it will be highly desirable to have this important observation made at several points, especially in high southern latitudes, and generally speaking at points as remote as possible from those at which it has already been determined. The selection of these must depend on local circumstances, as regards convenience for landing the instruments and executing the operations, as well as on the times of arrival at the several points.

It would also be desirable, if a convenient opportunity occurs, to swing the pendulums on the top of some high mountain; in which case they should also be swung at the foot of the same mountain, in order to determine the difference produced by the elevation, or other effect of the high land.

Another experiment which it would be desirable to make, is to swing the pendulum on a large field of fixed ice, as far from the land as possible; and likewise on the nearest shore to such position. In all these cases more than one pendulum should be used; and

at least three knife edges should be employed, in order to guard against any unforeseen anomaly that may arise.

It is scarcely necessary to state, that the direction of the line of motion, with respect to the magnetic meridian, should be noted at each station.

3. TIDES.

Our knowledge of the tides is so incomplete that there are few coasts on which good tide observations will not be valuable, especially if they are made with a due apprehension of the purposes to which they should be directed. One of these purposes is to determine the manner in which the tide *travels* from one part of the ocean to another; and in order to answer this purpose the observer must ascertain the *establishment*, or time of high water with reference to the moon's transit. The interval at which the high water follows the transit of this luminary is not constant; it varies to the amount of about eighty minutes in the course of a semilunation, according to the law expressed below in the Table of the Semimenstrual inequality, p. 43; and hence the *corrected establishment*, or *lunitidal interval*, as also the *vulgar establishment*, or time of high water at new and full moon, may be determined approximately by observations made at any period of a lunation: but no determination can be very exact which does not include several days' observations.

The traveller or navigator who would contribute towards our knowledge of the motion of the tide ought to make tide observations at several places along the same line of coast, so as to ascertain the establishment at each place, and thus to determine in what direction and at what rate the tide travels. This it is desirable to have done on all coasts. In islands it is especially desirable to have observations on opposite sides of the island, so as to ascertain what part of the coast is first reached by the tide and what last.

Great variations will often be found to occur in the range of the tide (namely, the range from low water to high water) even in a line of coast of no great extent. In order that these variations may clearly come into view, it is proper to observe low waters as well as high waters.

Another purpose for which tide observations are necessary is to determine the laws of the tides at a given place. The laws of the tides, as applicable to practical uses, are commonly assumed to be nearly the same at all places. If this were the case, all that it would be necessary to know, in order to obtain the laws for any particular place, would be the establishment of the place, and the range (greatest, least, or mean) of the tide. In fact, however, it is found that the semimenstrual inequality of the times varies considerably from place to place, and that the semimenstrual inequality of the range is not proportional to the range itself. Hence it is desirable to make continued observations at several places, so as to compare their semimenstrual inequalities. It is probable also that other corrections (as those for lunar and solar parallax and declination) differ at different places in the same manner. Hence tide tables con-

structed for one place, and applied to another place by merely altering the establishment, will often be found very inaccurate.

There is one feature of the tides which, though nearly universal, has only been lately made a subject of observation, and which in many cases extremely modifies the phenomena. This is the *diurnal inequality*, or difference of the two tides on the same day. This difference affects both the heights and the times; commonly the former most; and is often so large as greatly to disguise the phenomena of the tides. In extreme cases indeed (when its effect either on the time or on the height is very great) it produces the appearance of one tide only in twenty-four hours. At places where opportunity occurs it would be very desirable to make observations which may determine this inequality; for we are at present actually ignorant whether a considerable inequality of alternate tides be the rule or the exception. Observations continued for a fortnight at any place would ascertain the existence of this inequality, but it would be necessary to observe for a considerably longer period in order to determine its amount and law with exactness. It is to be recollected that the inequality disappears once every fortnight, and changes from one tide to another when the moon passes from south to north, or from north to south declination.

As to the mode of making observations; when the water is still, its height, and the time of its reaching the greatest height (or the least) may be observed by means of a pole carefully divided into feet and inches, and fixed upright in the water; or by any equivalent contrivance. The graduations of the pole, if fixed, should be read from below upwards, and should commence or have their zero at a point so far below the level of low water as to admit of no possibility of the surface of the sea ever descending so far. By this means all the readings are positive, and all doubts and consequent inevitable mistakes of the + and — readings are obviated; the observed range of the tide is then in all cases the *difference* of the greatest and least semidiurnal readings—the mid-water point half their *sum*. The mean of all the mid-water points, in a long series of observations, gives the division of the scale corresponding to the mean level of the sea. In a short series the correction will be required for this, which, in the case of a single day's observations, may be considerable. The heights registered however should be those read off on the scale, and not those deduced therefrom by the subtraction of any assumed constant for the mean sea-level.

A much more exact and preferable mode of observation, however, is to use an upright tube or chamber, in which is a float carrying an upright measuring rod carefully graduated into feet and inches *from above downwards* (the zero of the scale being above the top of the rod, so that it would require to be prolonged, if it were required to *read off* the zero). This rod should work through a loose collar near the point where the height is read off (which must be done by a fixed index), and friction rollers may be applied if the float have but little *weight* and *buoyancy*. The tube or chamber should not be less than three or four inches in diameter, smooth on

the inside, and giving access to the water by a small opening about $\frac{1}{4}$ inch diameter near the bottom, but not so near as to allow the entry of sand, &c., and guarded from that of sea weed, or sea animals, by a grating. This contrivance will neutralize the effect of the waves on the float.

The time should be observed by a watch or clock properly regulated to mean solar time at the place. If it strike minutes, so much the better. Some observers have noted, as the time of high water, the time when the water *begins to fall*, which is manifestly, as a general rule, too late. Others when it *ceases to rise*, which taken as a rule, would give a result too early, and both liable to serious *mistakes* in irregular tides. If the observer follow either of these inaccurate methods, he should state which. The only exact method is for the observer to be on the watch at least a quarter of an hour before the expected time of high water, and to note the reading of the float at every entire minute from the instant he arrives to that when he desists; and his observations should be continued for not less than ten minutes after he begins to feel assured that the high water is past. If provided with a supply of engraved squares, he may then (at leisure or while the observations are proceeding) take the time in minutes for an abscissa and the readings in inches for ordinates, project the curve of high water,—round off its angles so as to destroy accidental jerks, (which will require a little practice and the exercise of a discreet judgement,) and both the time and height of high water will be at once indicated by the course of the curve with all the precision the observation is capable of. But should he not feel competent to this operation, (which however a few trials renders very easy,) he may select for one observed height when the water has been *certainly rising*, a corresponding equal height when it has been *certainly falling*, and take the mean between these for a time of high water. And the time being thus concluded for *each* observed rising height, to which a corresponding equal sinking height has been noted, the mean of all the times of high water so deduced will be to be taken for the true time. In all cases the original notes of the minutely observations should be preserved.

In must be recollected, however, that observations made in this manner must not be directly compared with those in which the surface ceasing to rise or beginning to fall is observed; allowance must be made for the time during which the surface is apparently stationary.

The height of the *zero point* of the readings, above some fixed and probably permanent mark or line, (which should be described accurately and circumstantially so that it may be easily recovered,) should be carefully ascertained. When the graduations are on a *fixed* pole, it is necessary for this purpose to level from the mark pitched upon, to any one (stated) of the lines of graduation. Thus, if the graduation of twenty feet is found to be eight feet above the fiduciac point chosen, the zero of the scale, were it prolonged so far downwards, would be twelve feet below it. When a float is used, it

is the difference of level between the *index* by which the reading off is made and the permanent mark, which must be ascertained.

Each observation should carry the observer's name or initials; and the time in which the observations are made, whether mean or apparent solar time, as also the clock's error, and how obtained, should be carefully stated. Mean time as above recommended is now universally prevalent.

Low water must be observed in the same manner (*mutatis mutandis*) as high. In cases where, from the slope of the shore and other causes, low and high waters cannot be observed at the same station, a levelling operation will be necessary to bring to exact coincidence the zeros of the two graduated scales which must then be necessarily employed.

Mr. Palmer has described in the Philosophical Transactions a self-registering machine, which is intended to give the time of high water. Such a machine is in operation in Her Majesty's dock-yard at Sheerness, and is described in the Nautical Magazine for October 1832. The principle consists in a style or pencil which is moved horizontally by the tide along the summit of a cylinder which is turned round slowly and uniformly; the pencil describes a curve upon paper wound round the cylinder, which curve indicates the fluctuation of the water. The motion of the tide being originally vertical is changed by a very simple mechanical contrivance. Another contrivance destined for the same purpose has been invented by Captain Lloyd.

The following is the form of registering tide observations employed under the direction of the Admiralty, in which it will be observed are noted,

1. The time and height of high water;
2. The time and height of low water;
3. The direction and force of the wind.

Register of the Tides at Portsmouth Dock-yard.

1834. January.		High Water.		Low Water.		Range of Tide.	Wind.	
		Time.	Height.	Time.	Height.		Direction.	Force.
Day.		h m	ft. in.	h m	ft. in.	ft. in.		
1	A.M.	3 15	19 3·5	8 20	8 11	10 4·5	N.N.W.	6
	P.M.	3 30	18 4·7	8 45	8 0·7	10 4	N.W.	4
2	A.M.	4 0	18 6	9 15	8 3	10 3	W.W. by N.	5
	P.M.	4 15	17 5·5	9 25	8 7	8 10·5	N. by W.	2

"The *Time* is *Mean Time*, obtained through the Royal Naval College; and the Dock-yard clock, which is used for ascertaining the *Times* of High and Low Water, is regulated thereby, by Mr. Smithers, Clock-maker, Portsea.

"The Height of the Tide is ascertained by Lloyd's Tide Gauge.

"The Line from which the Heights are measured is the Sill of the North Dock-gates."

In the above specimen-register the force of the wind is indicated by figures, according to the following scale, contrived by Captain Beaufort:

0 *Calm.*		
1 *Light Air*	Or just sufficient to give steerage way.	
2 *Light Breeze*	Or that in which a well-conditioned man-of-war with all sail set, and clean full, would go in smooth water from	1 to 2 knots.
3 *Gentle Breeze*		3 to 4 knots.
4 *Moderate Breeze* ..		5 to 6 knots.
5 *Fresh Breeze*	Or that to which such a ship could just carry in chase, full and by	Royals, &c.
6 *Strong Breeze*......		Single-reefed topsails and top-gallant sails.
7 *Moderate Gale*		Double-reefed topsails, jib, &c.
8 *Fresh Gale*		Triple-reefed topsails, &c.
9 *Strong Gale*.........		Close-reefed topsails, and courses.
10 *Whole Gale*.........	Or that with which she could scarcely bear close-reefed main topsail and reefed foresail.	
11 *Storm*	Or that which reduces her to storm stay-sails.	
12 *Hurricane*	Or that which no canvas could withstand.	

The circumstances of high water admit generally of more accurate observation than those of low water.

The following table of the semimenstrual inequality serves to reduce observations made at any period of the lunation.

Moon's Age.	d 0											d 15
Time of Moon's transit	h 0	h 1	h 2	h 3	h 4	h 5	h 6	h 7	h 8	h 9	h 10	h 11
Lunitidal interval greater than mean (i. e. than *corrected establishment*)......................	m 11	−5	−02	−33	−37	−43	−19	15	36	43	37	24
Lunitidal interval less than at new or full moon (i. e. than *vulgar establishment*)	m 0	16	31	44	48	54	30	4	25	32	26	13
	less.							greater.				

The determining the period of the lunation by the *moon's age* is a very inaccurate method; the method by means of the moon's transit is much more exact.

By the above table, the establishment of the place, either the cor-

rected or the vulgar establishment, may be determined by tide observations made at any period of the lunation.

But the above table is not accurate, nor can any table be accurate for all places: not only because the *amount* of the semimenstrual inequality is different at different places, (as has already been noticed,) but also because the *epoch* of the inequality is (slightly) different for different places. And these differences can only be determined by continued observations at each place.

But it is probable that the epoch of the inequality is very nearly the same in neighbouring places.

4. METEOROLOGY.

The traveller should keep a complete meteorological register, skeleton forms for which have been prepared*. These are adapted for intervals of observation of six hours throughout the twenty-four; and although hourly observations be made, as is undoubtedly to be desired, yet the regular entry and reduction of the observations for the hours in the skeleton forms is nevertheless essential, for the sake of future comparison with those similarly entered and reduced at the fixed stations. So many references have lately been made to the Committee upon the subject of directions for meteorological observations, that they have embraced the opportunity of proposing a plan of extensive co-operation.

In the way of general remark on this subject it may be observed, that it is impossible to pay too much attention to the zero points of the instruments, especially the barometer. The thermometers and barometers should be carefully compared with those of the Royal Society; and one barometer should be continually referred to as a standard, whenever the instruments are landed by the navigator, and on his return on board, so as to detect and take account of any change which may have occurred in the interval. Nor should an opportunity be lost, if it presents itself, of comparing the standard barometer (by the intervention of portable ones) with the standard barometer of the Cape Observatory, and with that used at Port Arthur, Van Diemen's Land, in the meteorological register kept by Sir J. Franklin's orders by Mr. Lempriere, as well as with the standard at the observatory at Paramatta, and with any other instrument likely to be referred to as a standard or employed in research elsewhere.

The general fact that the barometer at the level of the sea does not indicate a mean atmospheric pressure of equal amount in all parts of the earth,—but, on the contrary, that the equatorial pressure is uniformly less in its mean amount than that at and beyond the tropics,—was first noticed by Von Humboldt, and has since been de-

* Messrs. Richard and J. E. Taylor, (Red Lion Court, Fleet Street,) are directed to supply these skeleton forms at the charge of twenty shillings for 25 Pairs.

monstrated by the assemblage of many observations made during voyages and on land by Schouw, as well as by other observations, an account of which will be found in the Reports of the Meteorological Committee of the South African Philosophical Society for 1836 and 1837. This inequality of mean pressure is a meteorological phenomenon of the greatest and most universal influence, as it is, in fact, no other than a *direct measure of the moving force*, by which the great currents of the trade-winds are produced; so that the measure of its amount, and the laws of its geographical distribution, lie at the root of the theory of these winds. The progress of barometric depression on approaching the line, and re-ascension in receding from it, will therefore be watched with interest proportionate to its intrinsic importance during the voyage outwards and homewards.

But it may very well happen that phenomena purely local, of the same nature, may exist, not as *cause* but as *effect*; in other words, that the regular currents once established may, in particular localities, determined by the configuration of continents and by the influence of oceanic currents, or other causes, form permanent eddies or atmospheric ripples, so to speak, under which the mean pressure may deviate materially from the general average. An instance of permanent barometric depression of this kind, in the neighbourhood of the sea of Ochotzk, has been supposed by Erman; and a second seems to be pointed out in the neighbourhood of Cape Horn, by some remarks stated to have originated with Captain Foster; and it is not impossible that something of the same kind, but of an inverse character, may be found to obtain in that remarkable district of Siberia mentioned by Erman, where, during winter, clouds are unknown and snow never falls; and it is somewhat curious to notice that the localities in question are not far from antipodes to each other.

In the passages of navigators across the equator (especially should the ships be delayed by calms), opportunity may be presented of determining the amount of diurnal barometric fluctuation, apart from the interfering influence of land and sea breezes, or their equivalents far inland, which in all land observations encumber and disturb this somewhat obscure phenomenon; as well as for ascertaining, also apart from those influences, the existence or non-existence of that difference between the diurnal and nocturnal maxima and minima, which has been proved to exist in some localities, and surmised to be general*.

Connected with the equatorial barometric depression, and the ascensional current of heated air which produces that depression, is a phenomenon which may serve to elucidate the mechanism of this current in its origin, as well as to illustrate the mode in which ascending currents occasionally produce rain. It cannot be supposed that the whole body of the equatorial atmosphere rises *en masse*, or with any regularity or steadiness. Such a movement would be out of analogy with what we know of the movements of fluids in general.

* See Reports of Met. Com. S. A. Phil. Soc. above referred to.

Its *tendency* to rise is general, but this tendency is diverted by a thousand local influences, and concentred on particular points, where it results in ascending columns and sheets, between which wind-flaws, capricious in their direction and intensity, and often amounting to sharp squalls, mark out the course of their feeders and of the indraft of cooler air from a distance to supply their void. Now the existence of such ascending columns is rendered frequently visible in a very unequivocal way, by vast piled-up masses of cloud of that peculiar form which has been called *cumulostratus,* the bottom being flat and ill-defined, the upper parts towering to an immense height, and ragged with great protuberances. From the bases of these great cumular piles are almost constantly seen to descend those violent showers so common in the calm latitudes.

It would be interesting on many accounts to obtain *measures,* even if somewhat vague, of the altitudes at which the *bases* of these clouds rest, as well as of the height of their summits, and to measure the temperature of the rain which falls from them at successive periods, as they pass over the ship, so as to ascertain whether the rain which falls along their axis be not colder (from coming at least in part from a greater elevation) than that from their skirts. The vapour plane, in such circumstances, being nearly or precisely uniform over vast tracts of sea, the altitude of the base of such cloud vertically overhead may be considered the same as that of any other favourably situated for measure. In fact the determination of the *mean height of the vapour plane* at and near the equator is one of high meteorological import, and is connected by no circuitous steps with all the most interesting questions regarding the distribution of aqueous vapour over the globe and the irrigation of the continents.

There can be little need to call the attention of navigators to anything relating to winds, storms, lightning, &c.; yet there are some points to which attention may be expressly drawn, viz. to such distribution and movements of the clouds as indicate the existence at the same time of an upper and an under current of wind moving in opposed or differing directions. In such cases, the sun, moon, or a star should be taken as a point to fix the eye. In storms the barometer should be very assiduously noted in relation to the varying phases of the gale and the changes of wind, and particularly to those sudden shifts of wind which characterize revolving storms. The Committee are not aware that the state of the barometer during "a white squall" has ever been very carefully noted from instant to instant; or that it, or the more sensitive sympiesometer, have been referred to during the approach and recess of a waterspout.

The phenomena of ordinary thunder-storms may be thought to afford little matter for remark, and extraordinary ones will be noted of course. Yet there is one point to which we should wish that some attention might be paid,—it is the sudden gush of rain which is almost sure to succeed a violent detonation immediately over-head. Is this rain a *cause* or a *consequence* of the electric discharge? Opinion would seem to lean to the latter side, or rather, we are not aware

that the former has been maintained or even suggested. Yet it is very defensible. In the sudden agglomeration of many minute and feebly electrified globules into one rain drop, the quantity of electricity is increased in a greater proportion than the surface over which (according to the laws of electric distribution) it is spread. Its tension therefore is increased, and may attain the point when it is capable of separating from the *drop* to seek the surface of the *cloud*, or of the newly-formed descending body of rain, which, under such circumstances, and with respect to electricity of such a tension, may be regarded as a conducting medium. Arrived at this surface, the tension for the same reason becomes enormous, and a flash escapes.

The following points should be observed, with a view to this mode of regarding the formation of lightning. 1st. The actual electric state of *that* rain which follows suddenly after a discharge originating vertically over head.

2nd. Whether lightning occurs without rain *in the immediate point where it originates*, or at least without a rapid formation and increase of cloud at that point.

3rd. Whether lightning proceeds from a cloud undergoing actual diminution from evaporation.

4th. Whether the cumular clouds, already noticed as continually forming and raining in the calm latitudes, send forth flashes of lightning; and if so, under what conditions, and with what effects.

Observations of Auroræ form a highly interesting subject. Their effects on the magnetic needle should of course be narrowly watched; and all their phenomena should be minutely registered, such as the formation, colour, extent, situation, movement, and disappearance of arches, patches, banks, and streamers. In particular, attention should be drawn to an appearance which sometimes occurs, and which cannot but be regarded as highly instructive. It consists in *pulsations* propagated with more or less swiftness through *patches* of sky *of definite forms*, which however become visible only in successive portions, as the pulse traverses them, giving the idea of masses of vaporous matter not visible *per se*, but rendered fitfully so, either by a band of light cast in succession over every part of them from without, or by a temporary phosphorescence developed within their substance when traversed by electric matter. Such pulsations as above described formed very remarkable features of the auroras of October 12, 1833, and of January 18, 1839.

Any indication of the *near vicinity* of auroral phenomena, or of their existence at a level below that of ordinary clouds, should be most minutely investigated at the moment, and carefully and circumstantially recorded.

On the nights from the 11th to the 14th of November the sky should be watched for the periodical meteors, whose existence seems now to be placed out of doubt; as also from the 9th to the 13th of August; and in general any remarkable display of shooting stars should be noted. The zodiacal light also should be observed in clear nights, with a view to the better defining its limits, and ascertaining if it be really, as some have supposed, variable in its extent

or lustre. Remarkable halos, parhelia, and other atmospheric phenomena, should be recorded, and careful measures of their dimensions taken with sextants or other instruments.

5. DISTRIBUTION OF TEMPERATURE IN THE SEA AND LAND.

Connected as this subject is with meteorology, it requires in some points of view to be considered apart. As the currents in the atmosphere are produced by the difference of temperature in its polar and equatorial regions, so it may be contended are those of the ocean by differences of temperature due to the same geographical causes. Such is the view taken by M. Arago in his elaborate instructions for the voyage of the *Bonite*, and it would appear undoubtedly more just than that which attributes them *wholly* to the friction and pressure of the winds. Nevertheless it must not be forgotten that there is an essential difference in the modes of action in the two cases. The sun's heat is effective in increasing the temperature of the air mainly *from below*, where it is in contact with the earth or water, both of which absorb the rays and communicate them to the air above. In the sea the case is otherwise: for the sun's rays are totally absorbed at the surface, and no ray reaches the bottom of any sea deserving the name. The temperature therefore of a deep stratum of water cannot be permanently maintained by the sun's *direct* heat greatly above what it would have independently of its direct action. Hence the motive power in a system of currents so originating must be sought, not in the *ascensional* force at the equator, but in a *descensional* one in the polar regions, or rather in that one polar region in which winter prevails. The order of the phenomena then is precisely the reverse of what obtains in the atmosphere; moreover the seat of the efficient agency is not only much less extensive than in the case of the atmospheric currents, but also subject to a semiannual shifting from one to the other extremity of the earth's axis, both which causes must tend greatly to diminish the average energy of the effect.

Practically speaking, the question resolves itself into one of fact, which observation only can decide. Is there in the whole column of water between the surface of the ocean and its bed at the poles, as compared with a column of equal depth at the equator and *in free communication with it*, a descensional power or not? and what is its amount? These questions can only be resolved by observations of the temperature and saltness of the sea, at various and considerable depths, in different latitudes, and under a great variety of local circumstances. The procuring such observations, and the preservation of specimens of the water, or the determination on the spot of their specific gravities, will afford a useful occupation in calms, and may be recommended as well worthy of attention. Theoretically speaking, the subject is more complicated than at first appears, since it cannot but be that some considerable portion of solar heat absorbed by the

equatorial continents,—in place of finding its way out of the earth by radiation at the poles, in the mode of subterraneous communication suggested by Fourier,—must escape through the bed of the ocean into its waters, and so be carried into their circulation.

The distribution of temperature over the globe must greatly depend on the intensity which the solar rays possess on attaining the surface of the earth after traversing the atmosphere in different latitudes. To subject this point to direct inquiry in a mode which after many years' trial has been found to give very satisfactory results, Actinometers are provided, and accompanied with very precise directions for their use. They should be observed only when the sky in the immediate neighbourhood of the sun is perfectly free from visible cloud. On the other hand, depression of temperature caused by diurnal and nocturnal radiation by the only means we at present possess for that purpose,—viz. that of thermometers blackened and exposed in reflectors to the sky,—will form a useful and valuable supplement to the actinometric researches. With a view to the collection of facts illustrative of the distribution of temperature on land, wherever a ship may touch with a prospect of remaining some days, no time should be lost, on landing, in burying in the earth one or more bottles (filled with spirits, if there should be danger of water freezing), well packed in cases, or boxes stuffed with non-conducting matter, such as woollen cloth, pounded charcoal, &c., but so as to leave easy access to the neck, which should be wide enough to introduce the bulb and stem of a good thermometer, so as to take the temperature of the contained liquid rapidly, before it can have become altered by exposure to the air on taking up the bottle. Bottles so arranged should be buried at depths of three, six, nine, twelve, &c. feet*, according to the facilities of penetrating the soil, and allowed to remain till the time of departure, so as to ensure their acquiring the precise temperature of the soil; and when taken up should immediately have the temperature of the included liquids ascertained. In case of very prolonged sojourn, monthly readings should be taken. The temperatures of all springs and wells should also be diligently noted and registered.

Opportunities for determining the temperature of the ocean at great depths must of course be rare; but at moderate depths it can always be done with comparatively little trouble, and the Committee therefore, suggest the propriety of making observations of this element at two moderate and constant depths (say 150 and 300 fathoms), by the aid of a self-registering thermometer attached to a sounding line whenever the ship's way shall be such as to allow their being made with precision.

6. CURRENTS OF THE OCEAN.

These are either subaqueous or superficial, and, like those in the atmosphere, both may coexist at the same place, with different direc-

* These are the depths adopted in Mr. Forbes's recent experiments.

tions and velocities. Of the former we know almost nothing, and of the latter but little compared with what would be desirable and most useful. The practice of daily throwing overboard a bottle corked and sealed with the latitude and longitude of the ship at noon ought not to be neglected. A single instance of such a record being found may suffice to afford indications of the utmost value, while the trouble and cost are too trifling to mention.

As no sea can be supposed absolutely motionless, the presence of a shoal, by casting up at the surface water which, but for it, would have continued to sweep along at a greatly lower level with the general body of the current, must bring the temperature of the surface water into nearer correspondence with that below. In low latitudes the surface water is hotter than that below; and accordingly it is a general remark, that the temperature sinks as the water shoals, or even in passing over banks whose depth is very considerable. If this theory of the phenomenon be correct, the contrary ought to be observed in situations where the surface water is colder than that below, as it is known to be under particular circumstances in the Polar Seas. In still larger tracts in high latitudes the seas have nearly a uniform temperature throughout their whole depth. In such circumstances should any superficial variation of temperature be observed in passing over a shoal or bank, it could only be ascribed to radiation. The subject is one of considerable interest to the navigator, as the approach to land or to shoal water is indicated by the thermometer with a high degree of sensibility. Recent observations of this kind exist, the one at entering Table Bay in 1834, the other at quitting it. In the former case the temperature fell 9° Fahr. in passing from deep water into the Bay; in the latter under reverse circumstances a rise of no less than 13° Fahr. was experienced, the temperature of the air remaining unaltered. The last-mentioned observations being very remarkable, the particulars are annexed.

Memorandum of Observations made on board the Earl of Hardwicke, H.E.I.C.S. by Captain Henning.

March 17th, 1839. Temperature of air at 5h P.M., four miles from Cape Town	64°·0
Of Sea	52°·0
5h 30m One mile north of Robben Island. Air	64°·0
Sea	57°·0
March 18th at sea. Air	64°·0
Sea	65°·0

Connected with the transcalescence of the air, is the transparency of the sea. The stimulus of the solar light no doubt affects the surface of mollusca at great depths, and numerous points of physical inquiry would be elucidated if we knew the co-efficients of extinction of the solar rays by pure sea water. As far as the luminous rays are concerned (or at least the chemical), the actual intensity of these rays at various depths might be very easily ascertained, both

for direct sunshine and that of cloudy daylight, by the aid of Mr. Talbot's sensitive paper; which, duly guarded from wet by varnish and interposition between glass plates, might be sunk, face upwards in a small frame, while a portion of the same paper, cut from the same sheet, should be similarly exposed on deck, and partially shaded, inch by inch, from minute to minute, (or for a smaller interval according to the sensitiveness of the paper,) with a view to immediate comparison between decks, by a light not strong enough to alter the tint.

A mode of photometric measurement may be also furnished by the sensitive paper above alluded to, by the exposure of a small portion of it to the sun at noon for a given time, suppose ten seconds, and subsequent comparison with a scale of tints. Paper duly prepared for these purposes was supplied for the use of the Antarctic expedition. During solar eclipses such paper ought to be exposed at intervals of five minutes.

The temperature of the soil under the direct influence of the sun as indicated by a thermometer barely covered with dry earth, is an element of importance to the botanist, and may be recommended as an apt accompaniment to actinometric observations. The thermometer used should have a scale reading at least to 180° Fahr.

The height of the line of perpetual snow, by whatever indications marked, should also be ascertained, wherever practicable.

7. DEPTH OF THE SEA.

Soundings to as great a depth as practicable should be taken wherever opportunities may offer. Great difficulty, however, is well known to exist in the way of procuring any exact result, or indeed any result at all in very deep seas: and various methods (all objectionable) have been proposed and tried. The maximum depth of the sea is a geological datum of such value, that a few failures incurred in attempts may very well be tolerated when placed in competition with the interest of even partial success.

8. VARIABLE STARS.

In clear weather many interesting observations might be made by any one acquainted with the constellations, or provided with a celestial map, as to the comparative lustre and variability of stars. Especially we would point out to the attention of such an observer the stars α Hydræ et Crateris as certainly, and δ Orionis as probably, variable; the former at its greatest brightness being equal to ϵ Argûs, and at its least equal or somewhat inferior to δ Argûs, which are the best stars for comparison with it. Its period of change, however, being only very imperfectly known, additional observations would be valuable. The remarkable star η Argûs should also be compared with others of the same apparent brightness, or nearly so, with a view to continue the history of its late extraordinary change of lustre. And the Committee earnestly recommend to any one who may undertake such observations, to form a list of a certain moderate number of stars, graduating

from the first magnitude downwards by almost insensible steps, and having rendered himself familiar with them, to note their arrangement in order of brightness,—not once only, but on a great many nights, forming on each occasion separate independent judgements; trusting on no account to any printed catalogue, and diligently recording and preserving his memoranda. Such observations are not part of the ordinary business of astronomical observatories, and are therefore neglected and abandoned to the amateur, the traveller, or the seaman in his night-watches, which they will be found to beguile of much of their tedium, and to reward by the frequent detection of variable stars not previously recognised as such.

9. REFRACTION.

The determination of refractions near the horizon, both of celestial and terrestrial objects in high latitudes, is a very interesting subject of study. They may be pursued in various modes, of which perhaps the easiest is to note the disappearance of particular stars behind the horizontal edge of a board, erected at some considerable distance from a fixed point of observation, and then to ascertain, with all precision, the altitude of the line of disappearance, accompanying such observation with the height of the barometer and thermometer. Vertical diameters of the sun or moon, when very near the horizon, with the corresponding altitudes, will also be of use, as well as measurements of the distances of two considerable stars on the same vertical, and direct measures of the altitudes of one and the same star in the progress of its diurnal course when near the horizon. The curve of terrestrial refraction might also be actually traced out by a levelling-staff. Any cases of unusual refraction, mirage, reduplication and inversion of images, and of lateral refraction, should be recorded.

10. ECLIPSES.

In annular or total solar eclipses the optical circumstances attending the formation and rupture of the ring should be minutely attended to, as well as the defalcation of light and heat, to be measured by their appropriate methods, as detailed in the Meteorological instructions.

In lunar *total eclipses* the occultations of stars, whether large or small, should be looked for, and any apparent projection on the disk noticed. Great attention should also be paid to the intensity, colour, and distribution of illumination over the disk during the *total* eclipse, as indicative of the general state of *the earth's* atmosphere in that great circle of the globe which at the moment is at right angles to the visual ray.

INSTRUCTIONS FOR MAKING METEOROLOGICAL OBSERVATIONS.

After maturely considering this subject, the Committee do not presume to anticipate that what they may suggest will not be liable to objections, for their object will be to include within their compass many excellent series of observations which are already in progress, rather than to propose a degree of theoretical perfection, the attainment of which the present state of the science may not perhaps admit of. Systematic co-operation is the essential point to which at present everything else should be sacrificed; and co-operation on almost any plan would most certainly be followed by more beneficial results than any number of independent observations, however perfect they might be in themselves.

The plan of co-operation should, in fact, be regarded at present as merely temporary and preparatory; but if steadily adhered to for a few years, it would certainly furnish the most perfect data for its own correction, which could then from time to time be applied with facility and precision.

The Committee are not without hopes that amateurs of science may be induced to conform to these suggestions, even at the temporary sacrifice of their own views and convenience; for no one can reflect on the immense amount of labour which is now rendered useless for want of the requisite uniformity and precision, without being convinced of the necessity of remedying an evil which has already been of too long standing, and continues to be a reproach to science. Many, of course, will not have it in their power to fill up the plan in all its details; but they will contribute greatly to forward the design, if, in such observations as they may find it convenient to make, they strictly comply with the rules proposed. They will be further encouraged to lend their aid to a comprehensive system, by the consideration that it will be adopted by the Government Observatories, as well as by those about to be established by the East India Company, and will of course be acted upon in the comparison and discussion of the observations made at these institutions by the scientific authorities who will be entrusted with the execution of this task.

The suggestions which the Committee wish to offer will relate, 1st, to the times of observation; 2ndly, to the situation of the instruments to be observed; 3rdly, to the correction of the observations; 4thly, to a form of registry, which may place many of the results in a striking point of view, and facilitate comparisons.

1. Barometers.

Times of observation.—The purposes of meteorological observations would be most perfectly and most expeditiously obtained by hourly observations throughout the year; but since in the case of private observers in general, and in few public establishments, such

a course of unremitting labour cannot be hoped for, it is necessary, for general purposes, to select periods at longer intervals calculated to embrace the extremes of the periodical oscillations to which the pressure of the atmosphere is subject, and to ensure that uniformity of system at different stations on which the value of such observations so much depends. It is probable that the hours of 3 A.M., 9 A.M., 3 P.M., and 9 P.M., nearly coincide with the daily maxima and minima of the barometric column at the level of the sea, over a large portion of the globe; and it is desirable that as extensive a comparison as possible should be instituted at these hours. At the magnetic observatories, it is provided that observations shall be made every second, or even, hour of Gottingen mean time throughout the twenty-four; so that there at least, and in all others which will act in concert and correspondence with them, the complete diurnal cycle will be satisfactorily observed. It would be uselessly super-adding labour to the already extensive task imposed on these establishments, to require observations also at the hours above recommended for general adoption as *Meteorological* hours. They will, therefore, content themselves with filling up the forms furnished them, as adapted to the meteorological hours, with observations made at the nearest *magnetic* hours to those named at each station.

It is not, however, too much to expect that hourly observations should be made, during 24 hours, once in every month, by those who profess to pursue meteorology in a scientific manner; and when this cannot be effected, it is of the utmost importance that they should be made at least four times in the year, namely, at the summer and winter solstices, and at the spring and autumn equinoxes. One of the results of these hourly observations would probably be the indication of the exact times of the daily maxima and minima of pressure at different stations, which, if not found to coincide with the hours provisionally adopted, might ultimately be substituted for them under future directions. At the magnetic observatories the instruments will be read off hourly, on the days set apart in each month for the *Magnetic Term observations*, and the two-hourly system of observation in all cases continuing uninterrupted, will in effect furnish corresponding observations on all other days, whether arbitrarily chosen to suit private convenience, or in pursuance of the system about to be proposed in the subsequent paragraphs.

Hourly observations at the equinoxes and solstices have been already instituted at numerous points both of Europe and America, at the suggestion of Sir John Herschel, whose directions should be strictly attended to. They are as follows:—

The days fixed upon for these observations are the 21st of March, the 21st of June, the 21st of September, and the 21st of December, being those, or immediately adjoining to those, of the equinoxes and solstices in which the solar influence is either stationary or in a state of most rapid variation. *But should any one of those 21st days fall on Sunday, then it will be understood that the observations are to be deferred till the next day, the 22nd.* The observation at each station should commence at 6 o'clock A.M. of the appointed days, and ter-

minate at 6 A.M. of the days following, according to the usual reckoning of time at the place.

The commencement of each hour should be chosen, and every such series of observations accompanied by a notice of the means used to obtain the time, and, when practicable, by some observation of an astronomical nature by which the time can be ascertained within a minute or two.

Travellers provided with meteorological instruments who may be stationary on any of these days, may use them with advantage on such opportunities. Such as may ascend high mountains are recommended, *cæteris paribus*, to choose one of these days as affording a greater probability of securing a complete series of corresponding observations than any other; for which reason these observations cannot be too strongly recommended to *residents* in mountainous countries. The geologist, nay even the surveyor, may find his account in traversing his field, barometer in hand, on one of these days, provided he have reason to presume that there exist observers in its neighbourhood who take a part in these observations.

It is to be hoped that to scientific meteorological observers the six-hourly observations may not be found to be impracticable throughout the year; but in any case where it may be impossible to observe regularly at 3 A.M., an effort should be made to include that hour on the days of the new and full moon, and quadratures, or at least on the days of the new and full moon;—as it must be borne in mind, that in what concerns the great meteorological questions on which the most interesting features of the subject depend, the night is quite as important as the day, and has been hitherto far too much neglected.

Whatever hours, however, may be selected for the regular series of observations, the greatest care should be taken not to insert in the register anything deduced by interpolation from observations made at other hours, or anything in short but what has been actually observed.

It is much to be wished that occasional observations may be made under remarkable circumstances, such as during great rises or great falls of the barometer, at the period of great storms, earthquakes, &c.; but such observations should be registered apart.

The barometer should be placed in an apartment subject to as little variation of temperature as possible, and in a good light; and to facilitate night observations, an arrangement should be made for placing behind it a light screened by a sheet of white paper, or other diaphanous substance. Great care should be taken to fix it in a perpendicular position by the plumb-line. Its height must be carefully ascertained above some permanent and easily-recoverable mark, either in the building in which it is situated, or in some more permanent building, or rock, in its immediate vicinity; and no pains should be spared to ascertain the relation which such mark may bear to the level of high and of low water at spring tides, and ultimately to the mean level of the sea.

Changes in the adjustments of meteorological instruments should

be most carefully avoided; but whenever any alterations may be absolutely necessary, they should be made with all deliberation, scrupulously noticed in the register, and the exact amount of the change thence arising in the reading of the instrument under re-adjustment ascertained. As far as possible, registers of meteorological observations should be complete; but if, by unavoidable circumstances of absence, or from other causes, blanks occur, no attempts to fill them up by general recollection, or by the apparent course of the numbers before and after, should ever be made.

The observatories established by her Majesty's Government are furnished with two barometers each, of Newman's construction—the one a standard, and the other portable; and they are accompanied by accurate directions for fixing and observing them.

The standard instrument is of large dimensions, its tube being of the diameter of 0·6 inch. It requires two adjustments: 1st, The whole scale, which is of brass, is moveable, and terminates in an ivory point, which is carefully brought down to the surface of the mercury in the cistern, and the two are known to be accurately in contact when the actual point and its reflexion appear just to touch one another. The scale is laid off from this point from an authentic standard.

2nd. The second adjustment is that of the vernier, in which the upper part of the scale terminates, to the surface of the mercury in the tube. For this, both the back and front edge are made to coincide, and brought down so as to form a tangent to the curve, and just to exclude the light between them at the point of contact. In making both these adjustments, it is desirable that the eye should be assisted by a magnifying glass. Before the observation is made the instrument should be slightly tapped, to free the mercury from any adhesion to the glass; but any violent oscillation should be avoided.

The portable barometer has only one adjustment, namely, that of the vernier to the upper surface of the mercury in the tube, which adjustment must be effected with the same precaution as in the case of the standard instrument.

This first reading may be entered in the column prepared for it in the register, and beside it the temperature of the mercury carefully read off from the thermometer which dips into the cistern.

In the case of the standard barometer the first measure is taken immediately from the surface of the mercury in the cistern, and it requires no correction for the different capacities of the tube and cistern. Neither does it require any correction for capillary action, as the large diameter of the tube renders this correction inappreciable.

The portable barometer, however, requires corrections for both these circumstances. For the purpose of the former, the *neutral point* is marked upon each instrument, or that particular height which, in the construction of the instrument, has been actually measured from the surface of the mercury in the cistern.

It is obvious that, in almost every case, the mercury will stand either above or below the neutral point: if above, a portion of the mercury

must have left the cistern to enter the tube, and consequently must have lowered the surface in the cistern; if below, a quantity of mercury must have left the tube, and, entering the cistern, raised the level of the mercury in it. For the correction of observations for this circumstance, the relation of the capacities of the tube and cistern have been experimentally ascertained, and are marked upon the instrument: thus, *capacity* $\frac{1}{50}$th, indicates that for every inch of elevation of the mercury in the tube, that in the cistern will be depressed one 50th of an inch. Thus, when the mercury in the tube is above the neutral point, the difference between it and the neutral point is to be divided by the capacity, and the quotient being added to the observed height, the result will be the corrected height. Or if the mercury at the time of observation should be below the neutral point, the difference of the two is to be divided as before, and the quotient to be subtracted from the observed height. Thus, suppose the capacity to be $\frac{1}{50}$th, the neutral point 30 inches, and the observed height 30·500 inches, the difference is 0·5 inch, which divided by 50 gives 0·01 inch to be added to the observed height, producing 30·51, the corrected height; or if the observed height be 29 inches, the difference, 1 inch, divided by 50, gives ·02 inch to be subtracted from the observed height, giving 28·980 inches for the corrected height.

The second correction required is for the capillary action of the tube, the effect of which is constantly to depress the mercury in the tube by a certain quantity inversely proportioned to the diameter of the tube. In the instruments furnished to the fixed observatories the amount has been experimentally determined during their construction, and marked upon the instrument; the quantity is always to be added to the height of the mercurial column, previously corrected as before. For the convenience of those who may have barometers, the capillary action of which has not been so determined, a table of the corrections for tubes of different diameters is placed in the Appendix, page 81.

The marine barometers furnished to the Antarctic Expedition differed in nothing from the other portable barometers but in the mode of their suspension, and the necessary contraction of the tubes to prevent oscillation from the motion of the ship, and require the same corrections.

When these two corrections have been made in the first reading of the portable barometer, it should agree with the direct observation of the standard barometer; and it is very desirable that frequent comparative observations should be made of the two instruments, in order to ascertain whether there may be any permanent difference between them. Should this be the case, the amount may be marked upon the instrument, and allowed for as an index error, in order that, if an accident should happen to one, the other may be substituted for it without detriment to the regular series of observations.

It is to be presumed that the portable barometer will frequently be employed in ascertaining the altitude of remarkable points in the vicinity of observatories.

The instruments furnished to the observatories established by her

Majesty's Government and the similar observatories in India have been all independently graduated and compared with the standard of the Royal Society; and in all cases it is desirable that such a comparison should be made with some standard instrument of authority, directly, or by means of a good portable barometer. In making such comparisons, all that is necessary is to record five or ten simultaneous readings of both instruments, deliberately made, at intervals of a few minutes from each other, after at least an hour's quiet exposure, side by side, that they may have the same temperature. If compared by two observers, each should read off his own barometer in his usual manner, then each should verify the other's result. By this means the zero of one standard may be transported over all the world, and that of others compared with it ascertained. To do so, however, with perfect effect requires the utmost care in the transport of the intermediate barometer, and is by no means an operation either of trifling import or of hurried or negligent performance: some of the greatest questions in meteorology depend on its due execution.

The next correction, and in some respects the most important of all, is that due to the temperature of the mercury in the barometer tube at the time of observation. To obtain this every barometer requires to have attached to it a thermometer, which in the instruments furnished to the observatories dips into the mercury in the cistern, and this must be read and registered at each observation of the barometer. In the appendix pages 82, &c. will be found a table calculated by Professor Schumacher, which gives for every degree of the thermometer and every half inch of the barometer, the proper quantity to be added or subtracted for the reduction of the observed height to the standard temperature of the mercury at 32° Fahr.

It must, however, be observed, that this table is only calculated for barometers whose scales are engraven upon a rod or plate of brass reaching from the level of the mercury to the vernier. In many barometers the scale is engraved upon a short plate of brass fixed upon the wooden frame of the instrument, and the compound expansion of the two substances can only be guessed at, but must be obviously less than if the whole length had been of brass. As a near approximation for such imperfect instruments, another table has been placed in the appendix page 88, in which the lesser expansion of glass has been substituted for that of brass. No scientific observer, however, would willingly use such an instrument.

Although all these corrections are necessary for the strict *reduction* of registered observations, they ought not to be applied to individual observations previously to registry. In the blank forms of register furnished to the observatories, one sheet is devoted to uncorrected observations, and a second to the corrected; and it is much to be wished that the proper reductions should be made as soon after the observations as possible.

2. Thermometers.

Times of observation.—The external standard thermometer should be observed and registered at the same times as the barometer, and

all the register thermometers may be read off at the time of the 9 A.M. observation, and their indices re-adjusted. But as double maxima frequently, and double minima occasionally, occur, in consequence of sudden changes of temperature, both the thermometers should be occasionally inspected with a view to ascertain whether the motion of either the mercury or the spirit has been reversed in an unusual manner; and such double maxima or minima should be recorded apart as *supernumerary*, with the dates and leading features of the case.

Each observatory was furnished with a standard mercurial thermometer, which was carefully compared with an authentic standard, to be deposited at the apartments of the Royal Society.

The spirit thermometers have been constructed with every possible attention to accuracy. A fixed point of temperature has been directly determined for each, at or about 0°, by means of a freezing mixture and comparison with a standard mercurial thermometer; and to render their indications accurate at still lower temperatures, the tubes are frustra of inverted cones, the rate of redaction of calibre being such as to compensate very nearly for the diminishing rate of the contraction of alcohol as we descend in the scale of temperature. For example, a column of mercury 5·10 inches long at the top of the instrument, changes to 5·40—5·43—5·46: the rapid change of the calibre at the top of the tube corresponding to the increased expansion of the spirits at the top of the scale. The specific gravity of the spirit employed is 822.

In general, however, accuracy would be most satisfactorily insured by selecting tubes of equal bores, and dividing the scales into equal degrees, which could be easily corrected, for the diminishing rate of the contraction of alcohol, by reference to proper tables.

It is recommended that all thermometers be carefully and frequently compared with the standard, and their differences, at one or more temperatures (the wider asunder the better), marked upon their scales and applied as index errors. This is particularly necessary with the register thermometers, whose construction renders them most liable to such errors.

In placing the standard thermometer, an exposure should be chosen perfectly shaded from the sun, where no reflected sunbeams from water, buildings, rocks, or dry soil can reach it, and which is easily accessible for observation. It should be *fixed*, not merely *hung*, upon a bracket projecting six inches from the wall, or other support to which it may be attached, and it must be *completely* sheltered from rain by a screen, so that the bulb shall never be wetted. In reading it, the observer should avoid touching, breathing on, or in any way warming it by near approach of his person; and in night observations particular care should be taken not to heat it by approximation of the light. The quicker the reading is done the better.

It is desirable that notice should be taken of all sudden and remarkable changes of temperature, although such occasional observations must not be recorded in the regular series.

The self-registering thermometers should be placed with the same precautions as the standard, and so fastened as to allow of one end being detached, and lifted up to allow of the indices within the tubes sliding down to the ends of the fluid columns, which they will readily do with the assistance of occasional tapping.

The self-registering thermometers are apt to get out of order by the indices becoming entangled, or from the breaking of the column of fluid. When this happens with the spirit thermometer, it may be rectified with ease by jerking the index down to the junction of the bulb and tube. The whole of the tube will at the same time become wetted with the spirit; and by setting it on end with the bulb downwards, the spirit will run together into one continuous column.

When the steel index of the mercurial thermometer becomes immersed in the mercury, it must be jerked in the opposite direction, till it, with the mercury which may be above it, is projected into the little bulb at the top of the tube. If this do not succeed, heat must be applied to the mercury-bulb, and when the index is fairly lodged in the air-bulb, by carefully warming the mercury-bulb with a spirit lamp having a very small flame, the mercury must be made to expand till it rises to the very top of the tube, and projects convexly into the air-bulb. The tube must then be placed upright, and, by tapping, the detached mercury will slip down beneath the steel index, and will fairly unite with the convex projection aforesaid. Now let the bulb cool, and the mercury will sink in one united column, and leave the index free.

Besides the regular series of observations of the temperature of the air, there are other occasional observations to be made of temperature under different circumstances, which might possess great interest.

The surface temperature of the water of the sea or of rivers may be conveniently obtained by taking up a bucket-full of water and stirring round the thermometer in it.

The temperature of the water of deep wells may be ascertained in the same way, and should be taken monthly, if near the residence of the observer. The temperature of rain should also be attended to at times; it may be determined by receiving the rain in a *linen* funnel, totally enclosed in a tin case to prevent cooling by evaporation from the linen.

The temperature of the soil at different depths is a point of considerable importance. For this purpose excavations should be made in a dry sheltered situation, 3, 6, and 9 feet deep, and lined with brick or earthenware tubes. In the bottom of these excavations earthenware quart bottles may be carefully placed, filled with water, spirit, or brine, and corked. They must be carefully covered with tow or cotton, and drawn up on the days of horary observation*, and their temperatures taken by an accurate thermometer, and registered apart.

As a general caution it may be mentioned, that the *standard* ther-

* See p. 38.

mometer should never be exposed to risk by application to such purposes, but thermometers which have been compared and corrected by comparison with it.

3. Actinometers.

Amongst the observations of highest importance must be ranked those of the force of solar and terrestrial radiation. The most perfect means of observing the former is afforded by the actinometer.

This instrument consists of a large hollow cylinder of glass, soldered at one end to a thermometer-tube, terminated at the upper end by a ball drawn out to a point, and broken off, so as to leave the end open. The other end of the cylinder is closed by a silver or silver-plated cap, cemented on it, and furnished with a screw, also of silver, passing through a collar of waxed leather, which is pressed into forcible contact with its thread, by a tightening-screw of large diameter enclosing it, and working into the silver cap, and driven home by the aid of a strong steel key or wrench, which accompanies the instrument.

The cylinder is filled with a deep blue liquid (ammonio-sulphate of copper), which ought to have been prepared some months beforehand, as it deposits a sediment when fresh, however clear or carefully filtered. This sediment, if deposited in the interior of the instrument, may be washed out with weak muriatic acid, which should itself be removed by water before refilling the instrument, and the ball at the top being purposely left full of air, and the point closed with melted wax, it becomes, in any given position of the screw, a thermometer of great delicacy, capable of being read off on a divided scale attached. The cylinder is enclosed in a chamber blackened on three sides, and on the fourth, or face, defended from currents of air by a thick glass, removeable at pleasure.

The action of the screw is to diminish or increase at pleasure the capacity of the hollow of the cylinder, and thus to drive, if necessary, a portion of the liquid up into the ball, which acts as a reservoir, or, if necessary, to draw back from the reservoir such a quantity as shall just fill it, leaving no bubble of air in the cylinder.

To use the instrument, examine first whether there be any air in the cylinder, which is easily seen by holding it level, and tilting it, when the air, if any, will be seen to run along it. If there be any, hold it upright in the left hand, and the air will ascend to the root of the thermometer-tube. Then, by alternately screwing and unscrewing the screw with the right hand, as the case may require, it will always be practicable to drive the air out of the cylinder into the ball, and suck down liquid, if any, from the ball, to supply its place, till the air is entirely evacuated from the cylinder, and the latter, as well as the whole stem of the thermometer-tube, is full of the liquid in an unbroken column. Then, holding it horizontally, face upwards, slowly and cautiously unscrew the screw, till the liquid retreats to the zero of the scale.

The upper bulb is drawn out into a fine tube, which is stopped with wax. When it is needed to empty, cleanse, and refill the instru-

ment, liquid must first be forced up into the ball, so as to compress the air in it. On warming the end, the wax will be forced out, and the screw being then totally unscrewed, and the liquid poured out, the interior of the instrument may be washed with water slightly acidulated, and the tube, ball, &c. cleansed, in the same way, after which the wax must be replaced, and the instrument refilled.

To make an observation with the actinometer, the observer must station himself in the sunshine, or in some sharply terminated shadow, so that without inconvenience, or materially altering his situation, or the exposure of the instrument in other respects, he can hold it at pleasure, either in full sun or total shadow. If placed in the sun, he must provide himself with a screen of pasteboard or tin plate, large enough to shade the whole of the lower part or chamber of the instrument, which should be placed not less than two feet from the instrument, and should be removeable in an instant of time. The best station is a room with closed doors, before an open window, or under an opening in the roof into which the sun shines freely. Draughts of air should be prevented as much as possible. If the observations be made out of doors, shelter from gusts of wind, and freedom from all penumbral shadows, as of ropes, rigging, branches, &c. should be sought. Generally, the more the observer is at his ease, with his watch and writing-table beside him, the better. He should have a watch or chronometer beating at least twice in a second, and provided with a second hand; also a pencil and paper ruled, according to the form subjoined, for registering the observations. Let him then grasp the instrument in his left hand, or if he have a proper stand (which is preferable on shore or in a building*), otherwise firmly support it, so as to expose its face perpendicularly to the direct rays of the sun, as exactly as may be.

The liquid, as soon as exposed, will mount rapidly in the stem. It should be allowed to do so for three or four minutes before the observation begins, taking care, however, not to let it mount into the bulb, by a proper use of the screw. At the same time the tube should be carefully cleared (by the same action) of all small broken portions of liquid remaining in it, which should all be drawn down into the bulb. When all is ready for observation, draw the liquid down to zero of its scale, gently and steadily; place it on its stand, with its screen before it, and proceed as follows.

Having previously ascertained how many times (suppose 20) the watch beats in five seconds, let the screen be withdrawn at ten seconds before a complete minute shown by the watch, suppose at $2^h\ 14^m\ 50^s$. From 50^s to 55^s, say 0, 0, 0, ... at each beat of the watch, looking meanwhile that all is right. At 55^s complete, count 0, 1, 2, ... up to 20 beats, or to the whole minute, $2^h\ 15^m\ 0^s$, keeping the eye not on the watch, but on the end of the rising column of liquid. At the 20th beat read off, and register the reading ($12^\circ{\cdot}0$), as in co-

* This may consist of two deal boards, 18 inches long, connected by a hinge, and kept at any required angle by an iron, pointed at each end. The upper should have a little rabbet or moulding fitting loosely round the actinometer, to prevent its slipping off.

lumn 3, A, of the annexed form. Then wait, watching the column of air above the liquid, to see that no blebs of liquid are in it, or at the opening of the upper bulb (which will cause the movement of the ascending column to be performed by starts), till the minute is nearly elapsed. At the 50th second begin to watch the liquid rising; at 55^s begin to count 0, 1, 2, up to 20 beats, as before, attentively watching the rise of the liquid; and at the 20th beat, or complete minute ($2^h\ 16^m\ 0^s$) read off, and instantly shade the instrument, or withdraw it *just out* of the sun and penumbra. Then register the reading off (43°3) in column 3, B, and prepare for the shade observation. All this may be done without hurry in 20 seconds, with time also to withdraw the screw if the end of the column be inconveniently high in the scale, which is often required. At the 20th second prepare to observe; at the 25th begin to count beats, 0, 1, 2, ... 20; and at the 20th beat, i. e. at $2^h\ 16^m\ 30^s$, read off, and enter the reading in column 3, A, as the initial shade reading (45°·2). Then wait as before till nearly a minute has elapsed, and at $2^h\ 17^m\ 20^s$ again prepare. At $17^m\ 25^s$ begin to count beats; at $17^m\ 30^s$ read off, and enter this *terminal* shade reading (42°·8) in column 3, B, and if needed, withdraw the zero.

Again wait 20^s, in which interval there is time for the entry, &c. At $17^m\ 50^s$ remove the screen, or expose the instrument in the sun; at 55^s begin to count beats; and at the complete minute, $18^m\ 0^s$, read off (14°·8), and so on for several alternations, *taking care to begin and end each series with a sun observation.* If the instrument be held in the hand, care should be taken not to change the inclination of its axis to the horizon between the readings, or the compressibility of the liquid by its own weight will produce a very appreciable amount of error.

In the annexed form column 1. contains the times, initial and terminal of each sun and shade observation. Column 2. expresses by

1. Date and times of observation. Feldhausen, 1837, Oct. 30. Initial.	Terminal.	2. Exposure, sun (⊙) or shade ×	3. Readings of the Instrument. A. Initial.	B. Terminal.	4. Change per minute. B − A.	5. Radiation in parts of scale.	6. Remarks.
h m s	m s						
2 15 0	16 0	⊙	+ 12·0	+ 43·3	+ 31·3	....	The times are reduced to *apparent* time, or to the sun's hour angle from the meridian.
16 30	17 30	×	45·2	42·8	− 2·4	34·75	
18 0	19 0	⊙	14·8	48·2	+ 33·4	35·40	Zero withdrawn.
19 30	20 30	×	28·0	26·8	− 1·4	34·85	
21 0	22 0	⊙	9·4	43·9	+ 33·5	34·75	
22 30	23 30	×	46·6	45·5	− 1·1	34·95	
24 0	25 0	⊙	9·0	43·2	+ 34·2	....	General mean per formula = 34·73 for $2^h\ 20^m\ 0^s$ of apparent time.

an appropriate mark, ⊙ and ×, the exposure, whether in sun or shade. Column 3. contains the readings, initial and terminal (A and B). Column 4. gives the values of B − A, with its algebraical

sign expressing the rise and fall per minute. And here it may be observed, that if by forgetfulness the exact minute be passed, the reading off may be made at the next 10^s, and in that case the entry in column 4 must be not the *whole* amount of B — A, but only $\frac{6}{7}$ths of that amount, so as to reduce it to an interval of 60^s precise. Column 5. contains the radiations as derived from successive triplets, $\odot \times \odot$, $\times \odot \times$, $\odot \times \odot$, &c. by the formula presently to be stated; and in column 6. are entered remarks, such as the state of the sky, wind, &c.; as also (when taken) the sun's altitude, barometer, thermometer, and other readings, &c.

The formula of reduction is as follows. Let $\odot$, $\times$, $\odot'$, $\times'$, $\odot''$, $\times''$, &c. represent the numbers in column 4, with their signs in order, as they stand, or the values of B — A. Then will the numbers in column 5 be respectively,

$$+\frac{\odot + \odot'}{2} - \times$$

$$-\frac{\times + \times'}{2} + \odot'$$

$$+\frac{\odot' + \odot''}{2} - \times'$$

$$-\frac{\times' + \times''}{2} + \odot'',$$

and so on, the algebraic signs being carefully attended to. Thus

$$34{\cdot}75 = +\frac{31{\cdot}3 + 33{\cdot}4}{2} + 2{\cdot}4$$

$$35{\cdot}30 = +\frac{2{\cdot}4 + 1{\cdot}4}{2} + 33{\cdot}4, \text{ \&c.}$$

The mean of a series not exceeding three or four triplets may be had by the formula

$$\frac{\odot + \odot' + \odot'' + \text{\&c.}}{n} - \frac{\times + \times' + \text{\&c.}}{n-1},$$

where n is the number of sun observations, the time corresponding being the middle of the middle shade observation.

A complete actinometer observation cannot consist of less than three sun and two shade observations intermediate; but the more there are taken the better, and in a very clear sunny day it is highly desirable to continue the alternate observations for a long time, even from sunrise to sunset, so as to deduce by a graphical projection the law of diurnal increase and diminution of the solar radiation, which will thus readily become apparent, provided the perfect clearness of the sky continue,—an indispensable condition in these observations, the slightest cloud or haze over the sun being at once marked by a diminution of resulting radiation.

To detect such haze or cirrus, a brown glass applied before the eye is useful, and by the help of such a glass it may here be noticed that solar halos are very frequently to be seen when the glare of light is such as to allow nothing of the sort to be perceived by the unguarded eye.

It is, as observed, essential that the instrument be exposed a few minutes to the sun, to raise its temperature in some slight degree. If this be not done, owing to some cause not very obvious, the first triplet of observations (sun, shade, sun) will give a radiation perceptibly in defect of the truth, as will become distinctly apparent on continuing the series. But it may be as well for a beginner to commence at once reading as soon as the instrument is exposed, and reject the first two triplets, by which he will see whether he has all his apparatus conveniently arranged, and get settled at his post.

When a series is long continued in a good sun, the instrument grows very hot, and the rise of the liquid in the sun observation decreases, while the fall in the shade increases; nay, towards sunset it will fall even in the sun. This phenomenon (which is at first startling, and seeming to impeach the fidelity of the instrument) is, in fact, perfectly in order, and produces absolutely no irregularity in the resulting march of the radiation. Only it is necessary in casting up the result (in col. 5.) to attend carefully to the algebraic signs of the differences in column 4, as in the following example (which, as well as that above given, is one of actual occurrence).

1. Date and times of observation. Wynberg, Nov. 21, 1837.		2. Exposure, sun or shade.	3. Readings of the Instrument.		4. Change per minute. B − A.	5. Radiation in parts of scale.	6. Remarks.
Initial	Terminal		A. Initial.	B. Terminal.			
h m s	m s						
6 5 15	....	...	....	....	....	....	Alt. of $\underline{\odot}$ = 7° 19′.
9 0	10 0	☉	+ 9·0	+ 9·7	+ 0·7		
10 30	11 30	×	23·0	10·8	− 12·2	11·25	
12 0	13 0	☉	34·0	31·1	− 2·6	9·25	
13 30	14 30	×	28·5	17·0	− 11·5	8·20	Cirrus haze coming on.
15 0	16 0	☉	12·0	8·0	− 4·0		
6 19 15	....	...	....	....	....	....	Alt. of $\underline{\subset}$ = 4° 37′.

Every series of actinometer observations should be accompanied with notices in the column of remarks of the state of the wind and sky generally, the approach of any cloud (as seen in the coloured glass) near to the sun; the barometer and thermometers, *dry* and *wet*, should especially be read off more than once during the series, if a long one, and, if kept up during several hours, hourly. The times should be correct to the nearest minute, at least as serving to calculate the sun's altitude; but if this be taken (to the nearest minute or two) with a pocket sextant, or even by a style and shadow, frequently (at intervals of an hour or less) when the sun is rising or

F

setting, it will add much to the immediate interest of the observations. When the sun is near the horizon, its reflection from the sea, or any neighbouring water, must be prevented from striking on the instrument; and similarly of snow in cold regions, or on great elevations in alpine countries.

Every actinometer should be provided with a spare glass, and all the glasses should be marked with a diamond; and it should always be noted at the head of the column of remarks; which glass is used, as the co-efficient of reduction from the parts of the scale (which are arbitrary) to parts of the *unit of radiation* varies with the glass used.

In the case of the actinometers sent out with the Expedition and to the fixed observatories, it was not practicable to ascertain these co-efficients for each instrument and each glass, owing to the total absence of any favourable opportunity of sunshine. The values of the parts of the respective scales of the instruments, as determined approximatively by careful measurement of the dimensions, were as follows:—

Marks of the Actinometers.		Multiplier for reducing parts observed to parts of a standard retained in possession, marked A 1.	Approximate value of one part of scale in Actines.
Maker's Mark.	Private Mark.		
1	K	1·4909	7·085
2	L	1·3726	6·523
3	M	1·4020	6·663
A 4	N	1·6550	7·864
A 5	O	1·4403	6·844
6	P	1·0608	5·041

The dimensions of the instruments which are used in these reductions are,

1st. The external diameter of the cylinder containing the coloured liquid, i. e. its mean diameter, if on measurement with fine callipers its two ends be found to differ.

2nd. The length of that portion of it which receives the sunbeam.

The product of these two data gives the area of the section of the sunbeam effective in raising the temperature, and which, though not all *equally* effective, by reason of the cylindrical form of the glass, is yet effective in *the same ratio* in all of them by reason of their general similarity of figure.

3rd. The content (in water grains) of 100 parts in length of the capillary tube used for the scale. This may best be determined by gauging it with mercury before it is soldered to the cylinder, and ought always to be so determined by the maker; but when fitted, this is impracticable, and the measurement of the element in question must be performed as follows:—

The instrument being placed horizontally, and allowed to attain the precise temperature of the apartment, let the liquid be brought to zero by the motion of the screw; after which let the screw be turned precisely one revolution, or half revolution (as the scale may require) *in*, and note the rise of the liquid in parts of the scale. This must be done several times, alternately screwing *in* and *out*. The screw must then be taken out; its threads counted, and the weight of water displaced from a narrow vessel exactly full, by the immersion of the whole length occupied by the thread exactly ascertained by a nice balance; after which a very simple calculation will give the value of the parts of the scale in water grains required; this process was followed in the case of the instruments above mentioned, and if carefully conducted is susceptible of great precision.

The glasses as well as the cylinders and capillary stems of the instruments, if accidentally broken, should have their fragments carefully preserved and labelled.

The unit of solar radiation to be adopted in the ultimate reduction of the actinometric observations is the *actine*, by which is understood that intensity of solar radiation, which at a vertical incidence, and supposing it wholly absorbed, would suffice to melt one millionth part of a metre in thickness, from the surface of a sheet of ice horizontally exposed to its action per minute of mean solar time; but it will be well to reserve the reduction of the radiations as expressed in parts of the scale to their values in terms of their unit until the final discussion of the observations.

Meanwhile, no opportunities should be lost of *comparing* together the indications of different actinometers under similar and favourable circumstances, so as to establish a correspondence of scales, which in case of accident happening to one of the instruments, will preserve its registered observations from loss.

The comparison of two actinometers may be executed by one observer using alternately each of the two instruments, thus,

Instrument A.	Instrument B.	A.	Etc.
⊙........ ×........ ⊙........	⊙........ ×........ ⊙........	⊙........ ×........ ⊙........	

beginning and ending with the same; though it would be more conveniently done by two observers observing simultaneously at the same place, and each registering his own instrument. An hour or two thus devoted to comparisons in a calm clear day, and under easy circumstances, will in all cases be extremely well bestowed.

Neither should each observer neglect to determine for himself the heat stopped by each of his glasses. This may be done also by alternating triplets of observation made with the glass on and off, thus,

Glass off.	Glass on.	Glass off.	Etc.
⊙.........	⊙.........	⊙.........	
×.........	×.........	×.........	
⊙.........	⊙.........	⊙.........	

beginning and ending with the glass off, and (as in all cases) beginning and ending each *triplet* with a sun observation. For the purpose now in question a very *calm* day must be chosen, and a great many triplets must be taken in succession. It will be found that a single thickness of the ordinary blueish or greenish plate glass stops about 0·20 $(=\frac{1}{5})$ of the incident calorific rays; a second glass about 0·16 (or a materially less proportion) of those which have escaped the action of the first. No two glasses, however, are precisely alike in this respect.

Very interesting observations may be made by two observers furnished with well-compared actinometers, the one stationed at the summit, the other at the foot of some great elevation, especially if the stations can be so selected that the observers shall be nearly in the line of the incident sunbeam at the time of observation, so as both to lie in the atmospheric column traversed by the rays. Many convenient stations of this kind might be found in mountainous countries; and by repeating the observation two or three times under favourable circumstances, interchanging observers and instruments, &c., and accompanying the observations with all circumstantial and local elements of precision, there is no doubt that the co-efficient of extinction of solar heat in traversing at least the lower strata of our atmosphere might be obtained with much exactness, and thus a highly valuable datum secured to science. The observers would, of course, agree to make their observations strictly simultaneous, and should, therefore, compare watches before parting.

The actinometer is also well calculated for measuring the defalcation of heat during any considerable eclipse of the sun, and the Committee would point out this as an object worthy of attention; as many eclipses invisible or insignificant in one locality, are great, or even total in others. The observations should commence an hour at least before the eclipse begins, and be continued an hour beyond its termination, and the series should be uninterrupted, leaving to others to watch the phases of the eclipse. The atmospheric circumstances should be most carefully noted during the whole series.

Though out of the question in the circumstances immediately under contemplation, it may not be amiss to remind aeronauts, that observations of the actinometer may, no doubt, be made with considerable ease and precision in the car of a balloon, and if accompanied with good barometric and hygrometric simultaneous observations aloft and below, as well as with a careful and copious registery of the temperatures of the air corresponding to each successive step of depression in the barometric column, would in every

point of view be most precious, especially as respects the intricate problem of astronomical refractions for the solution of which such a series of data could not fail to be most valuable, thus adding one to the many useful subjects of inquiry in those hitherto almost useless adventures. For the purpose of securing a steadily progressive ascent, it would be desirable that the ballast should be discharged continuously and not in large quantities at a time.

4. Radiating Thermometers.

As the actinometer can only be observed at intervals in perfectly clear weather, additional information with regard to solar radiation, of much interest, though not of so precise a nature, may be obtained, by the daily register of the maximum temperature of a register thermometer, with a blackened bulb exposed to the full action of the sun's rays. It may be placed about an inch above the bare soil, and screened from currents of air. The maximum temperature indicate by such a thermometer, even in cloudy weather, will generally be considerably above that of the air, and the maxima and mean daily maxima of its indications will, after a long series of observations, afford data of the utmost value to the history of climates. The bulb of the thermometer should be about half an inch in diameter, and it may be uniformly blackened with lampblack and varnish. The graduation should be made upon the glass stem, to prevent any inconvenience from the expansion and warping of the scale.

The measure of terrestrial radiation is of no less importance to the science of meteorology than that of solar radiation, but no perfect instrument has yet been contrived for its determination. Very valuable information, however, may be derived from the daily register of the minimum temperature of a register spirit-thermometer, the bulb of which is placed in the focus of a parabolic metallic mirror, turned towards the clear aspect of the sky, and screened from currents. The mirrors furnished to the observatories are of silver-plated copper, but planished tin-plate or zinc might be substituted without detriment. They are 6 inches diameter and 2 inches deep, and the thermometers which are graduated upon the stems pass through sockets in their sides, in which they may be accurately adjusted by corks. Their bulbs do not exceed half an inch in diameter.

Even in the daytime a thermometer so placed, and turned towards the clear sky, but away from the rays of the sun, will fall several degrees below the temperature of the surrounding air.

5. Hygrometers.

Times of observation.—Observations of the *dew-point* hygrometer are as desirable at the regular hours as those of the other meteorological instruments; but, as more difficulty attends the observation, it is more liable to omission, and it is of great importance that when one experiment only can be made, the most advantageous hour should be selected for the purpose. Now it is probable that the minimum

temperature of the air in the 24 hours may correspond with the minimum temperature of the dew-point; and for the attainment of a mean result, the time of the highest dew-point should be selected, which would not differ much from 3 P.M., at which hour the observation should on no account be omitted. The hygrometer should also be observed, if possible, at 9 A.M. and 9 P.M., but the minimum temperature might probably be substituted for the 3 A.M. observation without any material error.

At the magnetical observatories the dew-point will be observed at the nearest *magnetical* hours to the *meteorological* hours above fixed on (3 and 9 A.M. and P.M.).

Occasional observations of the dew-point under peculiar circumstances, as for instance in the inhabited apartments of houses or between the decks of the ships when laid up in their winter quarters in the polar regions, could not but afford information of high practical importance.

All the ether of the dew-point hygrometer should be driven by the warmth of the hand from the covered ball into the uncovered, previously to an observation, and the ether should be dropped from a dropping-bottle very slowly upon the former. The temperature of the interior thermometer should be carefully noted upon the first appearance of the ring of dew upon the black bulb, and also its temperature upon its disappearance: the mean of the two observations, should they differ, may be entered as the dew-point, together with the temperature of the air by the exterior thermometer.

The *wet-bulb* hygrometer can be observed without difficulty, by mere inspection, and the observation should never be neglected at the regular hours. It is probable that the temperature of evaporation thus ascertained may afford the means of accurately determining the dew-point, and of solving all the points of hygrometry; but until all the necessary corrections shall have been agreed upon, one of the most essential requisites must be its frequent and accurate comparison with the dew-point, directly ascertained.

The instruments supplied to the observatories are fitted with water-holders for keeping the bulb of the thermometer moist; but it should be observed, that the floss-silk, after being some time in use, has its faculty of conducting moisture greatly diminished, if not destroyed, and therefore requires to be renewed from time to time. When proper time can be afforded to allow the thermometer to take up its stationary temperature, it is, perhaps, best to moisten the ball for each observation. By urging upon the wet bulb a jet of air from a small double-bellows, the maximum depression may be obtained in a few seconds. In fact, the formula $f'' = f' - \frac{d}{88} \times \frac{p}{30}$ investigated by Dr. Apjohn, was tested under these circumstances, and he is of opinion that there will always be a small difference between the depression occurring in air at rest, and sweeping by the thermometer in a rapid current.

In this formula, f'' is the tension of steam at the dew-point; f' its tension at the temperature of the hygrometer; d the depres-

sion, or difference between the hygrometer and the air; 88 a coefficient depending upon the specific heat of air and the caloric of elasticity of its included vapour; p the existing and 30 the mean pressure of the air.

The hygrometers should be placed in the observatory, near to the standard thermometer, with which they should be frequently compared.

6. Vanes, Anemometers, and Rain Gauges.

The magnetic observatories and the Antarctic Expedition have been furnished with Osler's self-registering anemometer and rain-gauge.

In this instrument the direction of the wind is obtained by means of the vane attached to the rod, or rather tube, that carries it, and consequently causes the latter to move with itself. At the lower extremity of this tube is a small pinion working in a rack, which slides backwards and forwards, as the wind moves the vane; and to this rack a pencil is attached, which marks the direction of the wind on a paper ruled with the cardinal points, and so adjusted as to progress at the rate of 1 inch per hour, by means of a clock; the force is at the same time ascertained by a plate 1 foot square, placed at right angles to the vane, supported by two light bars running on friction-rollers, and communicating with three spiral springs in such a way that the plate cannot be affected by the wind's pressure without instantly acting on the springs, and communicating the quantum of its action by a wire passing down the centre of the tube, to another pencil below, which thus registers its degree of force. The rain is registered at the same time by its weight acting on a balance, which moves in proportion to the quantity falling, and has also a pencil attached to it, recording the results. The receiver is so arranged as to discharge every half inch that falls, when the pencil again starts at zero.

It is probable that the results obtained with this instrument would require correction for the varying effects of the eddy, which must be formed behind the board before they can be considered as exact measures of the pressure; and the effects of variations of temperature upon the force of the springs should be experimentally ascertained, particularly in very cold climates. This latter point may be determined by measuring the compression directly by the application of known weights.

Another self-registering anemometer has recently been constructed by Professor Whewell, which exhibits upon a diagram not only the direction and force, but the direction and integral effect of the wind, but which is more complex in its construction, and practically more liable to derangement.

In it a small set of windmill vanes, something like the ventilators of windows, are presented to the wind by a common vane, in whatever direction it may blow. The current, as it passes, sets these vanes in rapid motion, and a train of wheels and pinions reduces the

motion, which is thence communicated to a pencil traversing vertically, and pressing against an upright cylinder, which forms the support of the instrument: 1000 revolutions of the fly only cause the pencil to descend $\frac{1}{20}$th of an inch. The surface of the cylinder is covered with white paper, and the pencil, as the vane wavers, keeps tracing a thick irregular line, like the shadings on the coast of a map. The middle of the line may be easily traced, and it gives the mean direction of the wind, while the length of the line is proportional to the velocity of the wind and the length of time during which it blows in each direction.

Those who do not possess a register-anemometer may make use of the common vane and Lind's wind-gauge. The position of the former should be clear of all deflections and eddies from objects of the same or a higher level, and of course its position with regard to the true north should be clearly determined. In registering the direction of the wind it may be sufficient to use only 16 points of the compass.

Lind's wind-gauge for measuring the force or momentum of the wind is adjusted for use by filling it with water till the liquid in both legs of the siphon corresponds with the 0° of the scale. It is to be held perpendicularly, with the mouth of the kneed tube turned towards the wind, and the amount of the depression in one leg, and that of its elevation in the other, are to be carefully noted. The sum of the two is the height of a column of water which the wind is capable of sustaining at the time, and every body that is opposed to that wind will be pressed upon by a force equivalent to the weight of a column of water, having its base equal to the surface that is opposed, and its height equal to the altitude of the column of water sustained by the wind in the wind-gauge.

The height of this column being given, the force of the wind on a foot square is easily found by a table which will be given in the Appendix.

The observation of the gauge should always be made at the same point of a free space, and in gusty weather the maximum of the oscillation recorded. The most proper periods will be those of the other regular observations; but in great storms, or under other particular circumstances, occasional observations should be made, and registered apart.

Even in observatories which are provided with Osler's apparatus it is desirable that an accurate comparison should be made of the two anemometers.

The points most important to remark respecting the wind are,

1st. Its average intensity and general direction during the several portions of the day devoted to observation.

2ndly. The hours of the day or night when it commences to blow from a calm, or subsides into one from a breeze.

3rdly. The hours at which any remarkable changes of its direction take place.

4thly. The course which it takes in veering, and the quarter in which it ultimately settles.

5thly. The usual course of *periodical winds*, or such as remarkably prevail during certain seasons, with the law of their diurnal progress, both as to direction and intensity; at what hours, and by what degrees they commence, attain their maximum, and subside; and through what points of the compass they run in so doing.

6thly. The existence of crossing currents at different heights in the atmosphere, as indicated by the courses of the clouds in different strata.

7thly. The times of setting-in of remarkably hot or cold winds, the quarters from which they come, and their courses, as connected with the progressive changes in their temperature.

8thly. The connexion of rainy, cloudy or fair weather, with the quarter from which the wind blows, or has blown for some time previously.

The Rain-gauge may be of very simple construction. A cubical box of strong tin or zinc, exactly 10 inches by the side, open above, receives at an inch below its edge a funnel, sloping to a small hole in the centre. On one of the lateral edges of the box, close to the top of the cavity, is soldered a short pipe, in which a cork is fitted. The whole should be well painted. The water which enters this gauge is poured through the short tube into a cylindrical glass vessel, graduated to cubic inches and fifths of cubic inches. Hence one inch depth of rain in the gauge will be measured by 100 inches of the graduated vessel, and $\frac{1}{500}$th inch of rain may be very easily read off.

It is very much to be desired that, being of such easy construction, more than one of these gauges should be erected, or at least one placed with its edge nearly level with the ground, and another upon the top of the highest building, rock, or tree in the immediate vicinity of the place of observation, the height of which must be carefully determined; it having been satisfactorily ascertained that the height of the gauge above the ground is a very material element in the quantity of rain which enters it. The quantity of water should be daily measured and registered at 9 A.M.

7. Clouds and Meteors.

Many very highly-interesting observations may be made, without the aid of instruments, upon the clouds. In describing them Mr. Howard's nomenclature may be adopted with great advantage. By means of the clouds different simultaneous currents of wind may often be detected, the different directions of which should be carefully ascertained by referring their motions to some fixed object. Their gradual evaporation or precipitation should also be carefully noted, and particularly their regular disappearance at night, or their more irregular and sudden formation.

Rainbows, parhelia, haloes, &c., will of course be noted amongst the occasional remarks of the register; and an attempt should be made to express approximatively by numbers, the proportion which the overcast portion of the sky may bear to the clear space. For

this the hemisphere may be supposed to be divided into eight sections, and the cloudy portion may be expressed by the fraction $\frac{1}{8}$th or $\frac{5}{8}$ths, &c.

8. Electrometers.

The Committee are fully impressed with the high importance of regular observations on the electrical state of the atmosphere; but they are not prepared to suggest any means of effecting this desirable object, which will at all correspond with the present advanced state of electrical physics. At no distant period they hope to see supplied a defect which is certainly a reproach to science. In the meantime much valuable information might be acquired by observations of an electroscope, on one of the ordinary constructions connected with a lofty insulated wire.

In erecting such a wire, proper precautions should be taken against accidents by preparing a sufficient conductor in its immediate vicinity, by which a communication could be at once opened with the ground in case of any sudden and dangerous accumulation of the electric fluid.

As a temporary contrivance, a common jointed fishing-rod, having a glass stick well varnished with shell lac, substituted for its smallest joint, may be projected into the atmosphere. To the end of the glass must be fixed a metallic wire terminating in a point, and connected with an electroscope by means of a fine copper wire. If the wire be made to terminate in a spiral wrapped round a piece of cotton dipped in spirits of wine and inflamed, its power of collecting electricity will be sometimes doubled, but great precautions are necessary when this mode is employed. When the electroscope has been charged, the nature of the electricity may be tested in the usual way by excited glass or sealing wax.

The principal electroscopes which are capable of being employed to ascertain the electrical state of the atmosphere, or rather to compare its state at any given elevation with the state of the medium in contact with the instrument, are the following.

1. De Saussure's Electrometer, which consists of two fine wires, each terminated by a small pith ball, and adapted to a small metal rod fixed in the upper part of a square glass cover, upon one of the faces of which a divided scale is marked, in order to measure the angles of deviation of the two balls.

2. Volta's Electrometer, formed of two straws about 2 inches long and $\frac{1}{4}$th of a line broad, suspended from two small very moveable rings adapted to a metal rod: to measure the deviation of the straws a telescope with a nonius is employed.

3. Singer's Electrometer, consisting of two slips of gold leaf suspended from the rod.

4. Bohnenberger's Electroscope, formed of a single strip of gold leaf suspended from the conducting rod between two dry piles, the negative pole of one and the positive pole of the other being uppermost: this arrangement has the advantage of indicating the kind of electricity communicated to the conductor.

The observations made with these and similar instruments have demonstrated that in serene weather the electricity of the atmosphere is always positive with regard to that of the earth, and that it becomes more and more positive in proportion to its elevation above the earth's surface; so that if an observer be on a mountain or in a balloon, if his conductor be directed downwards to reach an inferior stratum of air, his electroscope will indicate negative electricity; and if it be sent upwards into a superior stratum, positive electricity will be manifested. Various means have been resorted to in these experiments, such as connecting one of the extremities of the conducting wire to a kite, a small balloon, or the head of an arrow, the other extremity remaining attached to the electroscope.

It has been ascertained by the observations of De Saussure, Schubler, Arago and others, that the positive electricity of the atmosphere is subject to diurnal variations of intensity, there being two maxima and two minima during the twenty-four hours. The first minimum takes place a little before the rising of the sun; as it rises, the intensity, at first gradually and then rapidly, increases, and arrives at its first maximum a few hours after. This excess diminishes at first rapidly and afterwards slowly, and arrives at its minimum some hours before sunset; it re-ascends when the sun approaches the horizon, and attains its second maximum a few hours after, then diminishes till sunrise, and proceeds in the order already indicated. The intensity of the free electricity of the atmosphere has also been found to undergo annual changes, increasing from the month of July to the month of November inclusive, so that the greatest intensity occurs in winter, and the least in summer.

In cloudy weather the free electricity of the atmosphere is still positive. During storms, or when it rains or snows, the electricity is sometimes positive and sometimes negative, and its intensity is always much more considerable than in serene weather. The electroscope will, during the continuance of a storm, frequently indicate several changes, from positive to negative.

The above is a short summary of almost all that is known respecting the laws of atmospheric electricity. It will be highly important to obtain a series of observations equal in accuracy to those made by Schubler at Frankfort in 1811 and 1812, simultaneously with the observations of the hygrometer, barometer, thermometer, &c. Combined observations at a number of different stations cannot fail to give us important information respecting the distribution of the free electricity in the atmosphere, and the extent and nature of the disturbances to which it is subject; but to render the results valuable it will be necessary to have instruments comparable with each other, and this may be a difficult matter to effect*.

Very recently a new method of investigating the electric state of the atmosphere has been proposed, likely to lead hereafter to very certain and valuable results; but it has not been sufficiently put in

* For a fuller account of what is known respecting atmospheric electricity, and the mode of conducting the observations, see Becquerel's *Traité de l'Electricité*, t. iv. pp. 78—125.

practice to enable the Committee to recommend, at the present moment, the best form of instrument for making simultaneous and comparable observations, or the proper precautions to guide the observer in manipulating it.

For the principle of this instrument we are indebted to Mr. Colladon of Geneva. He found, that if the two ends of the wire of a galvanic multiplier, consisting of very numerous coils well insulated from each other, were brought in contact, one with a body positively, and the other with a body negatively charged, a current of electricity passes through the wire, until equilibrium is restored; the energy and direction of this current is indicated by the deviation of the needle from the zero-point of the scale. This instrument is applied to the purpose of ascertaining and measuring the atmospheric electricity, by communicating one end of the wire with the earth, and allowing the other to extend into the region of the atmosphere, the electrical state of which is intended to be compared.

Thunder storms, of course, should be attended to; but it is of consequence also to notice distant lightning not accompanied with thunder audible at the place of observation, especially if it take place many days in succession, and to note the quarter of the horizon where it appears, and the extent which it embraces. In an actual thunder storm, especial notice should be taken of the quantity of rain which falls, and of the fits or intermittences of its fall, as corresponding, or not, to great bursts of lightning, as also of the direction of the wind, and the apparent progress of the storm with or against it*.

9. Registers.

The Register proposed by the Committee is comprised in two skeleton forms, which have been supplied to the magnetical observatories and to the Antarctic Expedition. This, it will be observed, applies to the meteorological forms about to be specified, independent of the more extensive and general forms for the registry of the magnetic observations, with their accompanying meteorological entries, with which the magnetical observatories will be supplied.

They are each calculated for one month's observation. *The first form* is for the insertion of observations as they are made in their uncorrected state. It consists of 12 principal divisions, and is ruled across for 31 days, and for the arithmetical convenience of casting up the sums and means of the quantities inserted. At the bottom of the sheet there is also a space provided for the hourly observations of the barometer and thermometers on *the twenty-first day of the month*, which will be more particularly described after the explanation of the principal divisions.

The outside compartments, both on the left and right of the sheet, are for the date of the month and the phases of the moon.

The second compartment is for the height of the barometer, and the temperature of the mercury for the four regular periods of observation.

* On these subjects the Committee especially recommend the attentive perusal of Arago's *Notice sur le Tonnerre.*

The third compartment is appropriated to the dew-point hygrometer, and contains also four columns for the four daily observations, each of which is subdivided into three; for the temperature of the air, the dew-point, and the difference between the two.

The fourth compartment is for the wet-bulb hygrometer, and is similarly divided and subdivided for the temperature of the dry- and wet-bulb thermometer, and for their differences.

The fifth compartment is prepared for the maxima and minima of temperature, and is divided into three. In the first division are to be recorded the maxima and minima of thermometers carefully placed in the shade and screened from radiation. In the second, the maxima of a blackened thermometer exposed to the sun, and the minima of a thermometer placed in a metallic mirror, and radiating freely to the clear sky. The third is devoted to occasional observations of the actinometer under favourable circumstances.

The sixth compartment is for the temperature of the surface-water of the sea, or of any river in the immediate neighbourhood of the observatory.

The seventh compartment is prepared for observations upon the direction and force of the wind at the four regular hours of registry. In the left-hand column of each division is to be recorded the direction of the vane, and in the right-hand column the height of Lind's gauge, in tenths of an inch of water.

In the eighth compartment the amount of rain is to be registered once in the day; and in the ninth, the electrical state of the atmosphere, if possible, at the four periods, 3 A.M., 9 A.M., 3 P.M., and 9 P.M.

The tenth compartment is appropriated to remarks on the clouds, and weather generally; and in the eleventh is to be noted, at noon, the longitude and latitude at sea.

On a careful review of the month's observations, the maxima and minima results should have the algebraic signs + and — respectively affixed.

The second form is devoted to the corrected results of the observations, and to the optical comparison together of some of them, by their projection upon a scale of equal parts.

The upper half of the sheet is vertically divided into two equal parts, each prepared for half the month's observations, and accordingly ruled across into sixteen spaces for the daily observations, and two for the sums and means of the quantities. Each half is also divided into five compartments.

The first is for the date of the month and the phases of the moon.

The second for the corrected height of the barometer at 32° Fahr.

The third is appropriated to the elastic force of the aqueous vapour corresponding to the dew-point, and which may be taken from Table V. in the Appendix, p. 89.

The fourth is for the maximum and minimum of temperature, and the mean of the two.

And the fifth for occasional remarks.

The lower half of the sheet is also vertically divided into two equal

parts, each of which is similarly divided into 31 columns for the daily observations of a month; and these again subdivided into four, for the six-hourly observations of each day. The vertical lines thus formed are divided into 6 inches; and each inch into tenths of an inch, and half-tenths, by horizontal lines.

The left-hand compartment thus ruled, is intended for the projection of curves of temperature; for this purpose each tenth of an inch upon the scale must be reckoned a degree, which will be divided by the faint line into halves.

The value of the degree may be arbitrarily fixed, and inserted in the margin according to convenience. Towards the upper part of the scale the results of the six-hourly observations should each be marked by a dot in its appropriate space, and the dots may be afterwards connected by a line.

The temperatures of the dew-point, or of the wet-bulb thermometer, or the mean temperature, may be compared with this primary result by projecting their curves in a similar way beneath it; and should the observations of these points be less frequent than four times in the day, the daily spaces may easily be divided accordingly.

The right-hand compartment is appropriated to the projection of curves of pressure, and the four daily observations of the barometer are to be marked by dots towards the upper part of the scale of inches, and afterwards connected by a line. Towards the lower part of the scale the elastic force of the vapour is to be noted, and the marks to be similarly connected by a line.

On either the scale of temperature or of pressure, occasional comparisons may be made with results obtained at other stations, which, if judiciously selected, cannot fail to prove of high interest and importance. They should, however, be laid down in pencil, or marked by a fainter line.

At the bottom of the first skeleton form will be found a space prepared for the 24 hourly observations of the *twenty-first day* of the month, both in their uncorrected and their corrected state. It is divided into four compartments for 6 hours each. The instruments which can with most facility be observed in this manner, are the barometer with its attached thermometer, and the dry- and wet-bulb thermometers; and columns are appropriated to each of these. It is desirable that the means of each 6 hours should be calculated, and spaces have been provided accordingly for the arithmetical operations.

In casting up the sums and calculating the *means*, care should be taken in all cases to verify the results by repetition; and the Committee recommend in every instance, before adding up the columns, to look down each to see that no obvious error of entry (as of an inch in the barometer, a very common error) may remain to vitiate the mean result. The precaution should also be taken of counting the days in each column, so as to make no mistake in the divisor.

The skeleton forms will be interleaved with blank pages, to facilitate computations and comparisons, and to afford space for other observations of atmospheric phenomena, which will perpetually pre-

sent themselves to those who make it their business or their pleasure to watch the changes of the weather on a judicious plan. The Committee, indeed, wish it to be understood, that, in the suggestions which they have offered, they have taken into consideration only such observations as are indispensable for laying the first foundations of meteorological science; some investigations of a more refined character they may, probably, make the subject of a future report.

As soon as the register of a month's observations has been computed, it should be copied, and the copy carefully compared with the original by two persons, one reading aloud from the original, and the other attending to the copy, and then exchanging parts,—a process always advisable whenever great masses of figures are required to be correctly copied.

A copy so verified should be transmitted regularly to such person or public body, as, under the circumstances, may be authorized or best adapted to receive and discuss the observations.

APPENDIX.

TABLES REFERRED TO IN THE SECTION ENTITLED "INSTRUCTIONS FOR MAKING METEOROLOGICAL "OBSERVATIONS."

Table I.

Correction to be added to Barometers for Capillary Action.

Diameter of Tube.	Correction for Unboiled Tubes.	Correction for Boiled Tubes.
inch.	inch.	inch.
0·60	0·004	0·002
0·50	0·007	0·003
0·45	0·010	0·005
0·40	0·014	0·007
0·35	0·020	0·010
0·30	0·028	0·014
0·25	0·040	0·020
0·20	0·060	0·029
0·15	0·088	0·044
0·10	0·142	0·070

Table II. Correction to be applied to Barometers with *brass scales*, extending from the cistern to the top of the mercurial column, to reduce the observation to 32° Fahrenheit.

Temp.	Inches.							
	20	20·5	21	21·5	22	22·5	23	23·5
°	+	+	+	+	+	+	+	+
0	·051	·053	·054	·055	·056	·058	·059	·060
1	·049	·051	·052	·053	·054	·056	·057	·058
2	·048	·049	·050	·051	·052	·054	·055	·056
3	·046	·047	·048	·049	·050	·052	·053	·054
4	·044	·045	·046	·047	·048	·050	·051	·052
5	·042	·043	·044	·045	·046	·048	·049	·050
6	·040	·042	·042	·044	·044	·046	·047	·048
7	·039	·040	·041	·042	·042	·044	·044	·046
8	·037	·038	·039	·040	·041	·041	·042	·043
9	·035	·036	·037	·038	·039	·039	·040	·041
10	·033	·034	·035	·036	·037	·037	·038	·039
11	·031	·032	·033	·034	·035	·035	·036	·037
12	·030	·030	·031	·032	·033	·033	·034	·035
13	·028	·029	·029	·030	·031	·031	·032	·033
14	·026	·027	·027	·028	·029	·029	·030	·031
15	·024	·025	·026	·026	·027	·027	·028	·029
16	·022	·023	·024	·024	·025	·025	·026	·026
17	·021	·021	·022	·022	·023	·023	·024	·024
18	·019	·019	·020	·020	·021	·021	·022	·022
19	·017	·018	·018	·018	·019	·019	·020	·020
20	·015	·016	·016	·016	·017	·017	·018	·018
21	·014	·014	·014	·015	·015	·015	·015	·016
22	·012	·012	·012	·013	·013	·013	·013	·014
23	·010	·010	·010	·011	·011	·011	·011	·012
24	·008	·008	·009	·009	·009	·009	·009	·010
25	·006	·007	·007	·007	·007	·007	·007	·007
26	·005	·005	·005	·005	·005	·005	·005	·005
27	·003	·003	·003	·003	·003	·003	·003	·003
28	·001	·001	·001	·001	·001	·001	·001	·001
	—	—	—	—	—	—	—	—
29	·001	·001	·001	·001	·001	·001	·001	·001
30	·003	·003	·003	·003	·003	·003	·003	·003
31	·005	·005	·005	·005	·005	·005	·005	·005
32	·006	·006	·007	·007	·007	·007	·007	·007
33	·008	·008	·008	·009	·009	·009	·009	·010
34	·010	·010	·010	·011	·011	·011	·011	·012
35	·012	·012	·012	·013	·013	·013	·013	·014
36	·013	·014	·014	·014	·015	·015	·016	·016
37	·015	·016	·016	·016	·017	·017	·018	·018
38	·017	·017	·018	·018	·019	·019	·020	·020
39	·019	·019	·020	·020	·021	·021	·022	·022
40	·021	·021	·022	·022	·023	·023	·024	·024
41	·022	·023	·024	·024	·025	·025	·026	·026
42	·024	·025	·025	·026	·027	·027	·028	·028
43	·026	·027	·027	·028	·029	·029	·030	·031
44	·028	·029	·029	·030	·031	·031	·032	·033
45	·030	·030	·031	·032	·033	·033	·034	·035
46	·031	·032	·033	·034	·035	·035	·036	·037
47	·033	·034	·035	·036	·036	·037	·038	·039
48	·035	·036	·037	·038	·038	·039	·040	·041
49	·037	·038	·039	·040	·040	·041	·042	·043
50	·038	·039	·040	·041	·042	·043	·044	·045

Table II. (continued).

Temp.	Inches.							
	20	20·5	21	21·5	22	22·5	23	23·5
	—	—	—	—	—	—	—	—
51°	·040	·041	·042	·043	·044	·045	·046	·047
52	·042	·043	·044	·045	·046	·047	·048	·049
53	·044	·045	·046	·047	·048	·049	·050	·052
54	·046	·047	·048	·049	·050	·051	·052	·054
55	·047	·049	·050	·051	·052	·053	·055	·056
56	·049	·050	·052	·053	·054	·055	·057	·058
57	·051	·052	·054	·055	·056	·057	·059	·060
58	·053	·054	·055	·057	·058	·059	·061	·062
59	·055	·056	·057	·059	·060	·061	·063	·064
60	·056	·058	·059	·061	·062	·063	·065	·066
61	·058	·060	·061	·062	·064	·065	·067	·068
62	·060	·061	·063	·064	·066	·067	·069	·070
63	·062	·063	·065	·066	·068	·069	·071	·072
64	·063	·065	·067	·068	·070	·071	·073	·075
65	·065	·067	·068	·070	·072	·073	·075	·077
66	·067	·069	·070	·072	·074	·075	·077	·079
67	·069	·071	·072	·074	·076	·077	·079	·081
68	·071	·072	·074	·076	·078	·079	·081	·083
69	·072	·074	·076	·078	·080	·081	·083	·085
70	·074	·076	·078	·080	·082	·083	·085	·087
71	·076	·078	·080	·082	·083	·085	·087	·089
72	·078	·080	·082	·084	·085	·087	·089	·091
73	·079	·081	·083	·085	·087	·089	·091	·093
74	·081	·083	·085	·087	·089	·091	·093	·095
75	·083	·085	·087	·089	·091	·093	·095	·098
76	·085	·087	·089	·091	·093	·095	·097	·100
77	·087	·089	·091	·093	·095	·097	·100	·102
78	·088	·091	·093	·095	·097	·099	·102	·104
79	·090	·092	·095	·097	·099	·101	·104	·106
80	·092	·094	·096	·099	·101	·103	·106	·108
81	·094	·096	·098	·101	·103	·105	·108	·110
82	·095	·098	·100	·103	·105	·107	·110	·112
83	·097	·100	·102	·104	·107	·109	·112	·114
84	·099	·101	·104	·106	·109	·111	·114	·116
85	·101	·103	·106	·108	·111	·113	·116	·118
86	·103	·105	·108	·110	·113	·115	·118	·120
87	·104	·107	·109	·112	·115	·117	·120	·123
88	·106	·109	·111	·114	·117	·119	·122	·125
89	·108	·111	·113	·116	·119	·121	·124	·127
90	·110	·112	·115	·118	·121	·123	·126	·129
91	·111	·114	·117	·120	·122	·125	·128	·131
92	·113	·116	·119	·122	·124	·127	·130	·133
93	·115	·118	·121	·124	·126	·129	·132	·135
94	·117	·120	·122	·125	·128	·131	·134	·137
95	·118	·121	·124	·127	·130	·133	·136	·139
96	·120	·123	·126	·129	·132	·135	·138	·141
97	·122	·125	·128	·131	·134	·137	·140	·143
98	·124	·127	·130	·133	·136	·139	·142	·145
99	·125	·129	·132	·135	·138	·141	·144	·147
100	·127	·130	·134	·137	·140	·143	·146	·150

Table II. (continued).

Temp.	Inches.								Temp.
	24	24·5	25	25·5	26	26·5	27	27·5	
	+	+	+	+	+	+	+	+	
0	·061	·063	·064	·065	·067	·068	·069	·071	0°
1	·059	·061	·062	·063	·064	·065	·067	·068	1
2	·057	·058	·060	·061	·062	·063	·064	·066	2
3	·055	·056	·057	·059	·060	·061	·062	·063	3
4	·053	·054	·055	·056	·057	·058	·059	·061	4
5	·051	·052	·053	·054	·055	·056	·057	·058	5
6	·049	·050	·051	·052	·053	·054	·055	·056	6
7	·046	·047	·048	·049	·050	·051	·052	·053	7
8	·044	·045	·046	·047	·048	·049	·050	·051	8
9	·042	·043	·044	·045	·046	·046	·047	·048	9
10	·040	·041	·042	·042	·043	·044	·045	·046	10
11	·038	·039	·039	·040	·041	·042	·042	·043	11
12	·036	·036	·037	·038	·039	·039	·040	·041	12
13	·033	·034	·035	·036	·036	·037	·038	·038	13
14	·031	·032	·033	·033	·034	·035	·035	·036	14
15	·029	·030	·030	·031	·032	·032	·033	·033	15
16	·027	·028	·028	·029	·029	·030	·030	·031	16
17	·025	·025	·026	·026	·027	·027	·028	·028	17
18	·023	·023	·024	·024	·025	·025	·025	·026	18
19	·021	·021	·021	·022	·022	·023	·023	·024	19
20	·018	·019	·019	·020	·020	·020	·021	·021	20
21	·016	·017	·017	·017	·018	·018	·018	·019	21
22	·014	·014	·015	·015	·015	·016	·016	·016	22
23	·012	·012	·012	·013	·013	·013	·013	·014	23
24	·010	·010	·010	·010	·011	·011	·011	·011	24
25	·008	·008	·008	·008	·008	·008	·009	·009	25
26	·005	·006	·006	·006	·006	·006	·006	·006	26
27	·003	·003	·003	·003	·004	·004	·004	·004	27
28	·001	·001	·001	·001	·001	·001	·001	·001	28
	−	−	−	−	−	−	−	−	
29	·001	·001	·001	·001	·001	·001	·001	001	29
30	·003	·003	·003	·004	·004	·004	·004	·004	30
31	·005	·006	·006	·006	·006	·006	·006	·006	31
32	·008	·008	·008	·008	·008	·008	·008	·009	32
33	·010	·010	·010	·010	·011	·011	·011	·011	33
34	·012	·012	·012	·013	·013	·013	·013	·014	34
35	·014	·014	·015	·015	·015	·015	·016	·016	35
36	·016	·017	·017	·017	·017	·018	·018	·019	36
37	·018	·019	·019	·019	·020	·020	·021	·021	37
38	·020	·021	·021	·022	·022	·023	·023	·023	38
39	·023	·023	·024	·024	·024	·025	·025	·026	39
40	·025	·025	·026	·026	·027	·027	·028	·028	40
41	·027	·027	·028	·029	·029	·030	·030	·031	41
42	·029	·030	·030	·031	·031	·032	·033	·033	42
43	·031	·032	·032	·033	·034	·034	·035	·036	43
44	·033	·034	·035	·035	·036	·037	·037	·038	44
45	·035	·036	·037	·038	·038	·039	·010	·041	45
46	·038	·038	·039	·040	·041	·042	·042	·043	46
47	·040	·041	·041	·042	·043	·044	·045	·046	47
48	·042	·043	·044	·045	·045	·046	·047	·048	48
49	·044	·045	·046	·047	·048	·049	·050	·050	49
50	·046	·047	·048	·049	·050	·051	·052	·053	50

Table II. (continued).

Temp.	Inches.								Temp.
	24	24·5	25	25·5	26	26·5	27	27·5	
°	—	—	—	—	—	—	—	—	°
51	·048	·049	·050	·051	·052	·053	·054	·055	51
52	·050	·052	·053	·054	·055	·056	·057	·058	52
53	·053	·054	·055	·056	·057	·058	·059	·060	53
54	·055	·056	·057	·058	·059	·060	·062	·063	54
55	·057	·058	·059	·060	·062	·063	·064	·065	55
56	·059	·060	·061	·063	·064	·065	·066	·068	56
57	·061	·062	·064	·065	·066	·068	·069	·070	57
58	·063	·065	·066	·067	·069	·070	·071	·073	58
59	·065	·067	·068	·070	·071	·072	·074	·075	59
60	·068	·069	·070	·072	·073	·075	·076	·077	60
61	·070	·071	·073	·074	·075	·077	·078	·080	61
62	·072	·073	·075	·076	·078	·079	·081	·082	62
63	·074	·076	·077	·079	·080	·082	·083	·085	63
64	·076	·078	·079	·081	·082	·084	·086	·087	64
65	·078	·080	·082	·083	·085	·086	·088	·090	65
66	·080	·082	·084	·085	·087	·089	·090	·092	66
67	·083	·084	·086	·088	·089	·091	·093	·095	67
68	·085	·086	·088	·090	·092	·094	·095	·097	68
69	·087	·089	·090	·092	·094	·096	·098	·100	69
70	·089	·091	·093	·095	·096	·098	·100	·102	70
71	·091	·093	·095	·097	·099	·101	·102	·104	71
72	·093	·095	·097	·099	·101	·103	·105	·107	72
73	·095	·097	·099	·101	·103	·105	·107	·109	73
74	·097	·099	·102	·104	·106	·108	·110	·112	74
75	·100	·102	·104	·106	·108	·110	·112	·114	75
76	·102	·104	·106	·108	·110	·112	·114	·117	76
77	·104	·106	·108	·110	·112	·115	·117	·119	77
78	·106	·108	·110	·113	·115	·117	·119	·122	78
79	·108	·110	·113	·115	·117	·119	·122	·124	79
80	·110	·113	·115	·117	·119	·122	·124	·126	80
81	·112	·115	·117	.119	·122	·124	·126	·129	81
82	·114	·117	·119	·122	·124	·126	·129	·131	82
83	·117	·119	·121	·124	·126	·129	·131	·134	83
84	·119	·121	·124	·126	·129	·131	·134	·136	84
85	·121	·123	·126	·128	·131	·133	·136	·139	85
86	·123	·126	·128	·131	·133	·136	·138	·141	86
87	·125	·128	·130	·133	·136	·138	·141	·143	87
88	·127	·130	·133	·135	·138	·141	·143	·146	88
89	·129	·132	·135	·137	·140	·143	·146	·148	89
90	·131	·134	·137	·140	·142	·145	·148	·151	90
91	·134	·136	·139	·142	·145	·148	·150	·153	91
92	·136	·139	·141	·144	·147	·150	·153	·156	92
93	·138	·141	·144	·147	·149	·152	·155	·158	93
94	·140	·143	·146	·149	·152	·155	·157	·161	94
95	·142	·145	·148	·151	·154	·157	·160	·163	95
96	·144	·147	·150	·153	·156	·159	·162	·165	96
97	·146	·149	·152	·156	·159	·162	·165	·168	97
98	·148	·152	·155	·158	·161	·164	·167	·170	98
99	·151	·154	·157	·160	·163	·166	·169	·173	99
100	·153	·156	·159	·162	·165	·169	·172	·175	100

Table II. (continued.)

Temp.	Inches.							Temp.
	28	28·5	29	29·5	30	30·5	31	
	+	+	+	+	+	+	+	
0°	·072	·073	·074	·076	·077	·078	·080	0°
1	·069	·071	·072	·073	·074	·076	·077	1
2	·067	·068	·069	·070	·072	·073	·074	2
3	·064	·065	·067	·068	·069	·070	·071	3
4	·062	·063	·064	·065	·066	·067	·068	4
5	·059	·060	·061	·062	·063	·065	·066	5
6	·057	·058	·059	·060	·061	·062	·063	6
7	·054	·055	·056	·057	·058	·059	·060	7
8	·052	·053	·054	·054	·055	·056	·057	8
9	·049	·050	·051	·052	·053	·054	·054	9
10	·047	·017	·048	·049	·050	·051	·052	10
11	·041	·045	·046	·046	·017	·048	·049	11
12	·042	·042	·043	·044	·045	·045	·046	12
13	·039	·040	·040	·041	·042	·013	·043	13
14	·037	·027	·038	·038	·039	·040	·010	14
15	·034	·035	·035	·036	·036	·037	·038	15
16	·032	·032	·033	·033	·034	·034	·035	16
17	·029	·030	·030	·031	·031	·032	·032	17
18	·026	·027	·027	·028	·028	·029	·029	18
19	·024	·024	·025	·025	·026	·026	·027	19
20	·021	·022	·022	·023	·023	·023	·024	20
21	·019	·019	·020	·020	·020	·021	·021	21
22	·016	·017	·017	·017	·018	·018	·018	22
23	·014	·014	·014	·015	·015	·015	·015	23
24	·011	·012	·012	·012	·012	·012	·013	24
25	·009	·009	·009	·009	·009	·010	·010	25
26	·006	·006	·007	·007	·007	·007	·007	26
27	·004	·004	·004	·004	·004	·004	·004	27
28	·001	·001	·001	·001	·001	·001	·001	28
	−	−	−	−	−	−	−	
29	·001	·001	·001	·001	·001	·001	·001	29
30	·004	·004	·004	·004	·004	·004	·004	30
31	·006	·006	·007	·007	·007	·007	·007	31
32	·009	·009	·009	·009	·009	·010	·010	32
33	·011	·012	·012	·012	·012	·012	·012	33
34	·014	·014	·014	·015	·015	·015	·015	34
35	·016	·017	·017	·017	·018	·018	·018	35
36	·019	·019	·020	·020	·020	·021	·021	36
37	·021	·022	·022	·022	·023	·023	·024	37
38	·024	·024	·025	·025	·026	·026	·026	38
39	·026	·027	·027	·028	·028	·029	·029	39
40	·029	·029	·030	·030	·031	·031	·032	40
41	·031	·032	·033	·033	·034	·034	·035	41
42	·034	·034	·035	·036	·036	·037	·037	42
43	·036	·037	·038	·038	·039	·040	·040	43
44	·039	·040	·040	·041	·042	·042	·043	44
45	·041	·042	·043	·044	·044	·045	·046	45
46	·044	·045	·045	·046	·047	·048	·049	46
47	·046	·047	·048	·049	·050	·151	·051	47
48	·049	·050	·051	·052	·052	·053	·054	48
49	·051	·052	·053	·054	·055	·056	·057	49
50	·054	·055	·056	·057	·058	·059	·060	50

Table II. (continued).

Temp.	Inches.							Temp.
	28	28·5	29	29·5	30	30·5	31	
°	—	—	—	—	—	—	—	°
51	·056	·057	·058	·059	·060	·061	·062	51
52	·059	·060	·061	·062	·063	·064	·065	52
53	·061	·063	·064	·065	·066	·067	·068	53
54	·064	·065	·066	·067	·068	·070	·071	54
55	·066	·068	·069	·070	·071	·072	·073	55
56	·069	·070	·071	·073	·074	·075	·076	56
57	·071	·073	·074	·075	·076	·078	·079	57
58	·074	·075	·077	·078	·079	·081	·082	58
59	·076	·078	·079	·080	·082	·083	·085	59
60	·079	·080	·082	·083	·085	·086	·087	60
61	·081	·083	·084	·086	·087	·089	·090	61
62	·084	·085	·087	·088	·090	·091	·093	62
63	·086	·088	·089	·091	·093	·094	·096	63
64	·089	·090	·092	·094	·095	·097	·098	64
65	·091	·093	·095	·096	·098	·100	·101	65
66	·094	·096	·097	·099	·101	·102	·104	66
67	·096	·098	·100	·102	·103	·105	·107	67
68	·099	·101	·102	·104	·106	·108	·109	68
69	·101	·103	·105	·107	·109	·110	·112	69
70	·104	·106	·108	·109	·111	·113	·115	70
71	·106	·108	·110	·112	·114	·116	·118	71
72	·109	·111	·113	·115	·117	·119	·120	72
73	·111	·113	·115	·117	·119	·121	·123	73
74	·114	·116	·118	·120	·122	·124	·126	74
75	·116	·118	·120	·122	·125	·127	·129	75
76	·119	·121	·123	·125	·127	·129	·131	76
77	·121	·123	·126	·128	·130	·132	·134	77
78	·124	·126	·128	·130	·133	·135	·137	78
79	·126	·128	·131	·133	·135	·137	·140	79
80	·129	·131	·133	·136	·138	·140	·143	80
81	·131	·134	·136	·138	·141	·143	·145	81
82	·134	·136	·138	·141	·143	·146	·148	82
83	·136	·139	·141	·143	·146	·148	·151	83
84	·139	·141	·144	·146	·149	·151	·154	84
85	·141	·144	·146	·149	·151	·154	·156	85
86	·144	·146	·149	·151	·154	·156	·159	86
87	·146	·149	·151	·154	·157	·159	·162	87
88	·149	·151	·154	·157	·159	·162	·165	88
89	·151	·154	·156	·159	·162	·165	·167	89
90	·153	·156	·159	·162	·164	·167	·170	90
91	·156	·159	·162	·165	·167	·170	·173	91
92	·158	·161	·164	·167	·170	·172	·175	92
93	·161	·164	·167	·170	·172	·175	·178	93
94	·163	·166	·169	·172	·175	·177	·180	94
95	·166	·169	·172	·175	·178	·180	·183	95
96	·168	·171	·174	·178	·181	·183	·186	96
97	·171	·174	·177	·180	·183	·186	·189	97
98	·173	·176	·179	·183	·186	·188	·191	98
99	·176	·179	·182	·185	·188	·191	·194	99
100	·178	·181	·184	·188	·191	·194	·197	100

Table III.

Correction to be applied to Barometers, the scales of which are engraven on *glass*, to reduce the observations to 32° Fahrenheit.

Temp.	Inches. 28·0	Inches. 28·5	Inches. 29·0	Inches. 29·5	Inches. 30·0	Inches. 30·5	Inches. 31·0	Inches. 31·5
25	+·017	+·017	+·017	+·018	+·018	+·018	+·019	+·019
30	+·005	+·005	+·005	+·005	+·005	+·005	+·005	+·005
35	—·007	—·007	—·007	—·008	—·008	—·008	—·008	—·008
40	—·019	—·020	—·020	—·020	—·021	—·021	—·021	—·022
45	—·031	—·032	—·032	—·033	—·033	—·034	—·035	—·036
50	—·043	—·044	—·045	—·046	—·046	—·047	—·048	—·049
55	—·055	—·056	—·057	—·058	—·059	—·060	—·061	—·062
60	—·067	—·068	—·069	—·071	—·072	—·074	—·075	—·076
65	—·079	—·081	—·082	—·083	—·085	—·086	—·088	—·089
70	—·091	—·093	—·094	—·096	—·098	—·100	—·101	—·103
75	—·103	—·105	—·106	—·109	—·111	—·114	—·116	—·118

Table IV.

Showing the Force of the Wind on a square foot for different heights of the Column of Water in Lind's Wind-gauge.

Height of the Column of Water.	Force of the Wind in Avoirdupois Pounds.	Common designation of such a Wind.
inches.		
12	62·5	
11	57·29	
10	52·08	Most violent hurricane.
9	46·87	
8	44·66	A very great hurricane.
7	36·55	A great hurricane.
6	31·75	A hurricane.
5	26·04	A very great storm.
4	20·83	A great storm.
3	15·62	A storm.
2	10·42	A very high wind.
1	5·21	A high wind.
0·5	2·60	A brisk gale.
0·1	0·52	A fresh breeze.
0·05	0·26	A pleasant wind.

In great degrees of cold, a saturated solution of sea salt may be used instead of water, the specific gravity of which is 1·244. If the force in the above Table for any height be multiplied by the specific gravity, the product will be the true force, as measured by the solution.

Table V.

Elastic Force of Aqueous Vapour for every degree of Temperature, from 0° to 124° Fahr.

Temp. Fahr.	Force. Inches of Mercury.	Temp. Fahr.	Force. Inches of Mercury.	Temp. Fahr.	Force. Inches of Mercury.	Temp. Fahr.	Force. Inches of Mercury.
0°	0·051	32°	0·186	63°	0.570	94°	1·562
1	0·053	33	0·193	64	0·590	95	1·610
2	0·056	34	0·200	65	0·611	96	1·660
3	0·058	35	0·208	66	0·632	97	1·712
4	0·060	36	0·216	67	0·654	98	1·764
5	0·063	37	0·224	68	0·676	99	1·819
6	0·066	38	0·233	69	0·699	100	1·874
7	0·069	39	0·242	70	0·723	101	1·931
8	0·071	40	0·251	71	0·748	102	1·990
9	0·074	41	0·260	72	0·773	103	2·050
10	0·078	42	0·270	73	0·799	104	2·112
11	0·081	43	0·280	74	0·826	105	2·176
12	0·084	44	0·291	75	0·854	106	2·241
13	0·088	45	0·302	76	0·882	107	2·307
14	0·092	46	0·313	77	0·911	108	2·376
15	0·095	47	0·324	78	0·942	109	2·447
16	0·099	48	0·336	79	0·973	110	2·519
17	0·103	49	0·349	80	1·005	111	2·593
18	0·107	50	0·361	81	1·036	112	2·669
19	0·112	51	0·375	82	1·072	113	2·747
20	0·116	52	0·389	83	1·106	114	2·826
21	0·121	53	0·402	84	1·142	115	2·908
22	0·126	54	0·417	85	1·179	116	2·992
23	0·131	55	0·432	86	1·217	117	3·078
24	0·136	56	0·447	87	1·256	118	3·166
25	0·142	57	0·463	88	1·296	119	3·257
26	0·147	58	0·480	89	1·337	120	3·349
27	0·153	59	0·497	90	1·380	121	3·444
28	0·159	60	0·514	91	1·423	122	3·542
29	0·165	61	0·532	92	1·468	123	3·641
30	0·172	62	0·551	93	1·514	124	3·743
31	0·179						

THE following letters from Baron Von Humboldt to the Earl of Minto, and from Professor Erman to Major Sabine, having been communicated to the Royal Society, the Committee have deemed it desirable that they should form a part of this publication, with the permission of the respective parties.

Letter from the Baron Alexander von Humboldt to the Earl of Minto.

MILORD:

Berlin, ce 12 Oct., 1839.

LORSQ'AU printems de l'année 1836, j'adressai une lettre à S. A. R. Mgr. le Duc de Sussex sur les moyens propres à perfectionner la connoissance du magnétisme terrestre par l'établissement de *stations magnétiques et d'observations correspondantes*, je sollicitai le concours puissant de la Société Royale de Londres en faveur de travaux qui, émanant à la fois de plusieurs grands centres scientifiques de l'Europe, pourroient conduire progressivement à la connoissance précise des lois de la nature. Ma démarche fut accueillie avec bienveillance, et la Société Royale daigna recommander à la protection spéciale du Gouvernement de Sa Majesté l'établissement de plusieurs stations permanentes dans les régions tropicales, et dans les parties tempérées de l'hémisphère austral.

Cette protection du Gouvernement a été accordée avec une munificence qui dépasse de bien loin l'espoir des hommes le plus ardemment occupés des variations du magnétisme terrestre, selon les trois coordonnées de déclinaison, d'inclinaison, et d'intensité absolue. Ce ne sont pas seulement des stations magnétiques qui seront fondées dans les lieux les plus propres à la manifestation des changemens que subit la distribution des forces; c'est une grande *expédition antarctique* qui a été ordonnée sous le commandement d'un savant et intrépide navigateur, le Capitaine James Clark Ross; expédition qui embrassera dans des travaux sagement preparés tous les problêmes du magnétisme terrestre, de la configuration du globe, de la distribution de la chaleur, du mouvement des eaux de l'océan, de la constitution géologique du sol, de la géographie des plantes et des animaux.

Je crois remplir un devoir sacré en offrant au Premier Lord de l'Amirauté, à Monsieur le Comte de Minto, l'hommage respectueux de la plus vive reconnoissance dont sont pénétrés tous ceux qui cultivent les sciences, et leur ont voué une vie laborieuse. Cette re-

connoissance est due au Ministre qui, dans des vues élevées et si favorables aux progrès de l'intelligence, a réalisé l'exécution du voyage antarctique. La bienveillance personnelle dont votre Excellence m'a honoré, pendant Son séjour à Paris et à la Cour de mon Souverain, me donne le courage de Lui communiquer en même-tems quelques considérations qui se rattachent au but principal d'une vaste et noble entreprise. Ma franchise ne sera pas mal interprétée.

La *variabilité* des phénomènes est ce qui caractérise le plus le magnétisme terrestre: variabilité selon une marche lente et périodique, quelquefois intermittente aussi, comme effet de perturbations brusques et instantanées. Il en résulte que pour approfondir les lois du magnétisme terrestre, il est d'une haute importance de connoître l'état magnétique du Globe à une même époque donnée, ou, du moins, selon des observations faites à des époques très rapprochées. Il y a presque déjà trente ans que, dans le *Recueil* de mes *Observations astronomiques*, j'ai indiqué combien il serait précieux pour la Physique du globe, si plusieurs bâtimens munis d'excellens instrumens, parcouraient simultanément l'équateur magnétique et les lignes sans déclinaison, pour fixer à la même époque, dans le vaste bassin des mers, la déclinaison, l'inclinaison, et l'intensité des forces magnétiques. J'insistai aussi, (malgré l'imperfection des instrumens et des méthodes d'alors,) d'après ma propre expérience, sur la possibilité de déterminer sur mer, et avec une précision suffisante, les variations de ces deux derniers élémens. (Rel. hist. T. 1. p. 262.) Je montrai combien ces déterminations océaniques sembloient offrir d'avantages, là, où les couches d'eau sont assez épaisses pour que l'on ait moins à craindre les perturbations locales dues à la constitution minéralogique du fond.

Guidé par des considérations analogues, j'ose exprimer le désir, que pour rendre plus fructueux encore l'immense travail qui sera exécuté en trois années, soit par l'expédition du Capitaine Ross, soit dans les nombreuses stations magnétiques répandues sur la surface des continens et des iles, Votre Excellence voulût bien ordonner simultanément quelques expéditions partielles et supplémentaires. Deux savans, auxquels nous devons des travaux importans sur la connoissance des variations du magnétisme terrestre, M. le Major Sabine et M. Lloyd, professeur à Dublin, m'ont déjà donné l'heureuse nouvelle que le Gouvernement de Sa Majesté enverroit à Otahiti, à cette métropole de l'Océan pacifique, illustrée par d'anciens travaux astronomiques, un officier très-instruit et muni d'appareils magnétiques. Le grand nombre de bâtimens de la marine royale qui se trouvent le plus souvent en station sur les côtes occidentales de l'Amérique du sud, et dans les mers de l'Inde, faciliteront peut-être les moyens de multiplier les investigations que j'appelle *supplementaires*, et dont, pour le moment, le but principal seroit la connoissance expérimentale de l'équateur magnétique, et des lignes sans déclinaison.

I. Un bâtiment muni d'instrumens propres à mesurer l'inclinaison, la déclinaison, et l'intensité, pourroit, en partant des côtes du Pérou, suivre l'équateur magnétique, ou la courbe d'inclinaison zéro, jusqu'

aux côtes de la péninsule de Malacca, et, si le vent le permet, jusq'au détroit de Bab-el-Mandeb. Un second bâtiment pourroit parcourir l'équateur magnétique depuis le Golfe de Guinée jusqu'aux côtes du Brésil. On détermineroit avec une grande précision astronomique les points du littoral où la courbe d'inclinaison zéro, qui n'est pas un grand cercle de la Sphère, coupe les continens et let iles: on apprendroit à connoître les changemens de sinuosité et le mouvement des *nœuds* (points d'intersection des équateurs magnétique et terrestre) qui ont eu lieu depuis les époques des voyages antérieurs. Comme les lignes isodynamiques et isoclines ne sont aucunement parallèles, il seroit à désirer que les intensités fussent aussi déterminées le long de l'équateur magnétique, ou dans sa proximité la plus immédiate.

II. Quant aux parties des lignes sans déclinaison qui deviennent accessibles aux navigateurs, j'oserai, Monsieur le Comte, les indiquer toutes, non dans le vain espoir que des observations simultanées puissent les embrasser dans leur ensemble pendant la durée du séjour du Capt. Ross dans les hautes régions antarctiques, mais seulement pour faciliter le choix à Votre Excellence selon les combinaisons fortuites que peuvent offrir des traversées ou les stations éphémères de bâtimens de la marine royale. Je n'ignore pas que d'après les grandes vues sur les véritables fondemens d'une *Théorie générale du magnétisme terrestre* qui sont dues à M. Gauss, soit la connoissance approfondie de l'intensité horizontale, soit la multiplicité et la sage répartition des points dans lesquels les trois élémens de déclinaison d'inclinaison et d'intensité ont éte simultanément mesurés, pour trouver la valeur de V (§. 4 et 27), et par conséquent aussi de $\frac{V}{R}$, sont les points vitaux du problème qu'a résolu l'illustre Géomètre: mais les besoins actuels du Pilotage, les corrections habituelles du rumb, et des chemins parcourus, donnent encore une importance speciale et *pratique* à l'élément de la déclinaison. On apprécieroit une détermination expérimentale, *c. à. d.* par observation immédiate, avant que l'édifice théorique ait pu être complété et terminé dans son ensemble; on l'apprécieroit d'autant plus que les lignes isogones ont un mouvement très-inégal dans les différentes portions de leurs traces, et que l'action combinée des *petites attractions magnétiques locales* cause des déviations partielles de la direction moyenne des lignes d'égale déclinaison, déviations qui intéressent la sécurité des routes, et qui resteront long-temps hors de l'atteinte de la théorie générale la plus solidement établie. Je signale ici de préférence la direction des lignes sans déclinaison, auxquelles des considérations de *Géographie physique* doivent conserver une partie de leur ancienne importance.

(*a.*) L'expédition antarctique, en arrivant, par l'ouest, de la Terre Kerguelen à celle de Van Diemen, aura traversé la ligne sans déclinaison qui remonte au nord vers la Terre de Nuyts (Australie.) Il seroit important de fixer astronomiquement, comme je l'ai fait observer pour l'équateur magnétique, les points méridionaux et septentrionaux du littoral de la Nouvelle Hollande, où la ligne de déclinaison zéro

traverse le continent australien, et de poursuivre cette courbe, d'abord vers l' O. N. O, et ensuite vers le nord, depuis la Baie de Vansittart, ou le Cap Bougainville, jusq' aux iles Maldives, et les attérrages de Surate dans l'Inde. Les connoissances acquises par les beaux travaux de Hansteen, d'Adolphe Erman et de George Fuss sur la grande sinuosité des lignes isogones de la Sibérie empêchent aujourd'hui de se former une idée exacte de la liaison de ces lignes avec les lignes correspondantes dans les Mers de l'Inde et de la Chine. D'après les cartes intéressantes qui accompagnent l'exposé de la *Théorie générale* par M. Gauss, la ligne de déclinaison zéro ne coupe le continent asiatique que près de l'entrée du Golfe Persique ; elle remonte directement de là vers le nord à la Mer Caspienne et à la Mer Blanche. D'après M. Barlow elle se replie du Golfe de Cambaye vers le N.E. et reparoît dans les Mers de la Chine et du Japon, entre l'extrémité septentrionale de l'Ile Formose et la péninsule Seghalienne.

Ce seroit jeter une vive lumière sur un des points les plus obscurs du magnétisme terrestre que de lever les doutes qui enveloppent le prolongement de cette ligne de déclinaison zéro de la mer des Indes, et de faire connoître, par des observations précises, la direction et la distribution des forces à l'ouest de l'Indus entre Candahar, Balkh, Koundouz, et le Pendjab (la Pentapotamie). Il est probable que la marche victorieuse des armées de S. M. vers Caboul, et le séjour des troupes dans l'Afghanistan pourront donner lieu à des recherches de ce genre, au moyen des petits appareils magnétiques que l'on destine pour l'Inde. Il resteroit à examiner pour la même époque, la position de la ligne zéro dans les mers du Japon au nord de l'Isle Formose, comme dans l'Océan Glacial dans la partie très-accessible entre Spitzberg et la Mer Blanche.

Suivre les traces de l'équateur magnétique, ou celles des lignes sans déclinaison, c'est gouverner (diriger la route du vaisseau) de manière à couper les lignes zéro dans les intervalles les plus petits, en changeant de rumb chaque fois que les observations d'inclinaison ou de déclinaison prouvent qu'on a dévié.

(*b.*) Si du système oriental, ou de l'ancien continent, nous passons au système magnétique americain et atlantique, nous aurions à désirer la détermination simultanée des portions de la ligne sans déclinaison qui remonte à l'est de la Géorgie du sud vers St. Salvador au Brésil, quitte le continent près de Maranham, et se dirige au N. O. vers le Cap Charles et la Baye de Chesapeak. Les mers que traverse cette ligne sont si fréquentées que de nombreuses observations magnétiques y ont été faites, et se trouvent conservées dans les archives du Dépôt de la Marine Royale ; mais il ne suffit pas d'avoir coupé souvent et à différentes époques la ligne zéro, il s'agit de la poursuivre, autant que les vents le permettent, dans toute son étendue. Je devrais hésiter, M. le Comte, à faire mention du prolongement le plus boréal de la ligne atlantique à travers le Canada et la Baie d'Hudson, mais je dois considérer la surface du globe dans son ensemble, et fixer l'attention des navigateurs sur les changemens qui peuvent être survenus dans les dernières années.

(*c.*) La Mer du Sud, si l'on en excepte les côtes du Japon n'a de nos jours pas de variation zéro. Le *nœud circulaire qui renferme l'archipel* des *Marquesas* près du minimum des variations orientales (5°) mérite de nouvelles investigations dont pourroit se charger le bâtiment qui suivrait l'équateur magnétique du Pérou vers l'Inde. La forme de ce nœud circulaire *c. à d.* l'espacement variable des courbes isogones qui le constituent, et le déplacement progressif du nœud entier, sont des phénomènes également remarquables et qui contrastent avec le grand nœud circulaire de l'Asie orientale, auquel, selon le mémoire de M. Gauss, appartient la courbe de déclinaison zéro des mers du Japon et de la Chine.

Je compte sur votre ancienne bienveillance, Milord, en osant vous importuner si longuement de considérations sur l'utilité que pourraient offrir des observations simultanées, par l'emploi d'instrumens et de méthodes semblables, dans les différentes régions des deux hémisphères. J'ai touché aux moyens de compléter les resultats de la grande expédition antarctique, et d'en augmenter la valeur. Votre Excellence choisèra dans sa sagesse, ce qui, parmi tant d'objets importans pour l'*art nautique* et pour la *Géographie physique*, pourra lui paroître d'une exécution facile. Je sais borner mes espérances.

Je supplie V. E. de jetter les yeux sur quelques *additions aux instructions scientifiques* que j'ose Lui adresser. C'est presque être présomptueux que de vouloir ajouter à un excellent travail, rédigé en partie par Sir J. Herschel. J'ai cédé aux instances amicales de MM. Sabine et Lloyd, et je vous supplie, Milord, de vouloir bien faire mettre entre les mains de Sir J. Herschel un écrit fragmentaire dans lequel ce grand astronome et savant physicien effacera librement tout ce qui lui paroîtra peu exact, ou moins digne de l'attention des voyageurs.

Je suis. &c., &c.

A. DE HUMBOLDT.

Additions fragmentaires aux "Instructions for the Scientific Expedition to the Antarctic Regions."

Les personnes qui sont chargées des observations scientifiques, ayant des connoissances très-variées, il suffit de leur rappeler avec la plus grande concision les points qui paroissent de quelque importance dans le cours de leurs travaux.

I. Forme de la Surface Continentale.

Mouvemens des terres par *soulèvement* ou par *dépression*, soit lents et progressifs, soit brusques et instantanés, toujours comme effet de la réaction de l'intérieur fluide d'une planète vers sa croûte plus ou moins consolidée.

Il seroit important de placer des marques sur les côtes des continens et des iles, à une élévation rigoureusement déterminée au

dessus des plus hautes marées. Je préférerois des barres de cuivre préparées d'avance en Angleterre, ayant une inscription de la date et le nom du Capitaine Ross. Un trait ou sillon creusé dans le rocher, réuniroit deux marques métalliques éloignées l'une de l'autre au moins de 15 pieds. Le sillon doit être très-exactement horizontal. Pour chaque endroit on aura vérifié l'élévation moyenne des marées d'une manière approximative. Des marques semblables, mais de fer et de 2 pieds de long, ont été placées (à ma prière, après mon retour de Sibérie) par M. Lenz, membre de l'Académie de St. Petersbourg, sur les côtes rocheuses de la Mer Caspienne près de Bakou (voyez Poggendorf, Annalen, t. xxvi. p. 364.). Les barres sont scellées par du plomb fondu.

II. Magnétisme Terrestre.

Tout ce qui a rapport à l'importance de la simultanéité des déterminations d'inclinaison, de déclinaison et d'intensité magnétiques a été consigné dans la lettre que j'ai eu l'honneur d'adresser à M. le Comte de Minto, Premier Lord de l'Amirauté. J'ai rappelé ce qui est relatif à la forme, et aux directions actuelles de l'équateur magnétique (courbe d'inclinaison zéro) et des lignes sans déclinaison. Je n'ajoute ici que le désir que l'on puisse observer en outre des époques prescrites par M. Gauss, aux époques astronomiquement importantes des *solstices* et des *équinoxes*, comme je l'ai fait conjointement avec M. Oltmanns en 1806 et 1807, pendant 5 et 6 jours et autant de nuits. A cause de la plus grande précision des instrumens actuels, 24 ou 36 heures suffiroient. Je signale aussi les points suivans :—Examiner les influences lunaires d'après les indications de M. Kreil, astronome de Milan. aujourd'hui à Prague; faire attention aux orages, aux grandes chutes de grêle ou de neige, aux jours couverts ou sereins; voir si des changemens atmosphériques modifient les phénomènes magnétiques d'une manière sensible et stable; examiner si sur mer ou sur les glaces polaires, on remarque quelque influence de la constitution minéralogique du fond; si des perturbations locales se font sentir sur mer, là ou l'on peut supposer que les eaux ne sont pas très-profondes. L'intensité des forces se trouvoit diminuée à la hauteur que M. Gay Lussac a atteinte en ballon: on reconnoit cette diminution, lorsqu'on corrige les observations de ce savant par la température des couches d'air qu'il a parcourues. La position dans un vaisseau à la surface des mers est une position semblable; moins par rapport à la surface moyenne de la terre, que par rapport à l'indépendance relative aux attractions locales. Les observations faites sur de hautes montagnes, au dessus de 2500 toises, (observations d'inclinaison et d'intensité recueillies soit par moi, soit tout récemment par d'autres voyageurs) donnent des résultats peu concordans à cause des perturbations dues aux couches soulevées de la croûte terrestre. Ces considérations sur le décroissement très-lent des forces magnétiques dans le rapport hypsométrique, et sur la petitesse de la profondeur moyenne de l'océan, méritent l'attention des physiciens. Même sur le sol volcanique de Rome, nous n'avons pas trouvé M. Gay Lussac et moi, de différence sensible dans l'intensité de la force horizon-

tale au Monte Pincio, à la Villa Borghese, et à Tivoli. Ces expériences seront très-aisées à répéter sur la glace, où l'on peut s'éloigner à de grandes distances du navire, et où les influences du fond de la mer, si elles existent, doivent se manifester au milieu de la marche uniforme des phénomènes d'intensité ou d'inclinaison.

Les tremblemens de terre m'ont paru agir quelquefois sur l'inclinaison. Multiplier les observations d'inclinaison horaire là ou les secousses sont fréquentes.

Les aurores boréales changent-elles parfois la force horizontale sans influer sur l'inclinaison? Y a-t-il quelque aspect particulier à cette classe d'aurores boréales ou australes, qui affectent peu les déclinaisons horaires de l'aiguille?

Observer de préférence les variations magnétiques aux époques où beaucoup d'étoiles filantes entrent dans l'atmosphère. Examiner si de grandes perturbations (les orages magnétiques) se répétent pendant plusieurs jours aux mêmes heures; si en général ces orages magnétiques ne sont pas beaucoup plus fréquens de nuit, lorsque le soleil ne règle et ne tempère plus, par son séjour au dessus de l'horizon, la marche de l'aiguille. Il est d'un vif intérêt de découvrir les rapports du magnétisme terrestre (et de ses manifestations variables) avec d'autres phénomènes physiques, soit dans les mouvemens qui dépendent du tems vrai (du passage du soleil par le méridien de chaque lieu), soit dans les mouvemens isochrones, *c. à d.* dans ceux dont on peut déduire la différence de longitude avec un degré de précision inattendue.

III. Mers.

Observer les différences de température dans la haute et la basse mer, comme l'influence que la pente plus ou moins rapide des accores produit sur le refroidissement des bas-fonds; mésurer la distance à laquelle les bancs de glace agissent sur la température des eaux de la surface. Les températures des couches inférieures de la mer ont acquis un nouvel intérêt depuis que dans le voyage de Kotzebue, M. Lenz, muni d'excellens instrumens, a trouvé souvent sous les tropiques (par 7° et par 21° de latitude, à 600 et 900 toises de profondeur) 2·21 et 2·44 du thermomètre centigrade, (Poggendorf, t. xx. p. 73,) et que l'on sait que le maximum de densité de l'eau pure n'est pas applicable à l'eau de mer. Le Capitaine Bérard, avec une ligne de sonde d'un millimètre de diamètre, est parvenu à sonder jusqu'à 1334 toises de profondeur (Bérard, *Description des Côtes d'Alger*, 1837, p. 41). Les thermomètres à minimum et à maximum de M. Magnus et de M. Walferdin sont d'un emploi très-précis comme l'ont prouvé les belles expériences de M. Arago dans les puits artésiens. C'est dans les courans océaniques d'une haute température que les sondes thermométriques seroient surtout d'un grand intérêt. Examiner si le courant d'eaux froides qui longe les côtes du Pérou jusqu'au Cap Pariña, où il dévie vers les Galapagos, et dans lequel j'ai trouvé par les 12° de latitude sud l'eau de la surface seulement à 12·4 Réaumur, quand hors du courant, la mer étoit à 22 R., prend sa source 75° à l'ouest du méridien

du Cap Horn par les 60° et 65° de latitude sud. Ce mouvement des eaux froides est il d'abord dirigé vers le nord-nord-est, et puis (sur le parallèle de 35° sud) vers l'ouest, en frappant contre les côtes du Chili, et se divisant sur ces côtes en deux courans vers le nord et le sud? Examiner la température de ce fleuve pélagique loin du littoral à l'ouest du Chili. (Voyez l'intéressante *Carte du mouvement des eaux dans le Grand Océan Austral, par le Capitaine Duperrey*, 1831, et l'Atlas Physique de Berghaus, Cahier I. No. 4.)

Employer différens moyens, ou de nivellement optique le long des mâts, ou de dépression d'horizon (si le soleil est visible), ou de privation du vent par les vagues (en mesurant en même tems l'inclinaison de la mâture,) pour déterminer, dans une tempête, loin des côtes, le maximum si souvent contesté de la hauteur des vagues. J'ai cru trouver ce maximum de 43 piés français, par le moyen de la dépression de l'horizon, dans la Mer du Sud, pendant une de ces tempêtes désignées sous le nom de Papagayos, à l'ouest des côtes de Guatimala. D'autres voyageurs croyent ce chiffre de beaucoup trop grand.

IV. Atmosphère.

Si la pression moyenne de l'air au niveau des mers diminue dans l'hémisphère boréal, depuis le parallèle de 55° vers les tropiques et vers l'équateur, elle paroît, par de certaines longitudes, diminuer aussi, entre les 55° et 68°, et puis augmenter de nouveau. D'après les recherches de M. Schouw, on trouve, à zéro de température et en appliquant avec M. Poggendorf la correction relative à la pesanteur, pour

	Nord.		Lignes *.
Christiansborg	$5\frac{1}{2}$°	Bar.	336·09
La Guayra	10		6·16
Palerme	38		8·00?
Naples	41		7·82
Londres	$51\frac{1}{2}$		7·53
Altona	$53\frac{1}{2}$		7·35
Danzig	$54\frac{1}{2}$		7·24
Edinburgh	56		6·46
Christiania	60		6·74
Bergen	60		6·02
Reikiavig	64		3·89
Godthaab	64		3·86
Upermavik	73		5·49
L'Ile Melville	$74\frac{1}{2}$		6·35
Spitzberg	$75\frac{1}{2}$		6·23

En faisant abstraction de la correction relative à la pesanteur, on auroit, pour La Guayra 336·98, pour Londres 337·33, pour Reikiavig 333·36, pour l'Ile Melville 335·61. (Poggendorf, t. xxvi. p. 241 et 475.) Il est important d'avoir ces chiffres sous les yeux pour les comparer avec les hauteurs moyennes du baromètre que

* Ancienne mesure de France.

les voyageurs obtiendront, réduites à zéro de température, par les différentes latitudes et longitudes de l'hemisphère austral.

On comparera aussi la direction moyenne des vents de l'année et des saisons avec la pression atmosphérique.

Quant à la direction du *tournoiement* du vent dans les deux hémisphères, effet de la rotation du Globe et de la vitesse des molécules d'air correspondant à chaque parallèle, je recommande les ingénieuses recherches de M. Dove dans les *Meteorologische Untersuchungen*, 1837, pp. 124—138. Déjà Bacon de Verulam a dit, dans le chapitre *De successione ventorum*: "Si ventus se mutet conformiter ad motum solis, *non* revertitur plerumque." La direction du tournoiement est opposée dans les deux hémisphères (*Churucca, Viage al Magellanes*, 1793, p. 15); mais ce fait, connu depuis long-tems des marins, n'avoit pas été examine sous le rapport de ces importantes influences météorologiques.

Examiner la températures des plages et la comparer à la température de l'air. Placer des thermomètres dans le sol à différentes profondeurs, sous différentes latitudes.

L'observation des *réfractions* par un froid très-intense deviendroit surtout importante, si par l'ascension à quelque montagne voisine et d'une élévation considérable, on pouvoit déterminer en même-tems le décroissement du calorique. Dans le voyage de la corvette *La Recherche* au Spitzberg et aux côtes de Laponie, on s'est servi de ballons captifs et de thermomètrographes, mais des expériences de ce genre sont d'une exécution peu facile. Le décroissement de la chaleur est si lent pendant de grands abaissemens du thermomètre, que les observations de réfraction de M. Svanberg faites en Laponie par 29° centésimaux audessous du point de la congélation donnent, d'après les formules de M. Laplace, un décroissement de 243 mètres par degré centésimal.

L'Ephéméride des étoiles filantes, publiée par M. Quetelet, sera indispensable aux voyageurs, pour fixer leur attention sur d'autres jours que ceux d'Août et de Novembre. Examiner si les mois de Fevrier et de Mai se signalent particulièrement, et si les jours des grandes chutes d'étoiles filantes il y a simultanément des traces d'aurores australes. L'Amiral Wrangel assure avoir observé souvent, dans son expédition aux iles des Ours et de Kolioutchin dans la Mer glaciale, que pendant les aurores boréales, certaines régions du ciel ne sont devenues lumineuses que lorsque des étoiles filantes les ont traversées. Les aurores australes laissent-elles des traces pendant le jour: ces traces se manifestent-elles par une certaine disposition linéaire de nuages, (*cumulito-stratus* du journal de M. le Capitaine Fitz-Roy,) également espacés? Ces rangées de petits nuages ou *bandes polaires* m'ont paru le plus souvent dirigées dans le méridien magnétique, p. e. sur le plateau de Mexico, quelquefois, surtout dans le nord de l'Asie, je les ai vues tourner progressivement pendant des nuits très-calmes du N. par l'E. N. E. à l'Est. Ces apparences ne seroient-elles que des effets de perspective, des convergences de stries parallèles, causées par des vents supérieurs?— Cette explication me paroît douteuse.

V. Zoologie.

Les mémorables travaux de mon ami et compagnon de voyage, M. Ehrenberg, et les rapports qu'offrent ces travaux, soit avec la connoissance intime de l'organisation d'animaux que l'on croyoit jadis d'une structure infiniment simple, soit avec la phosphorescence de l'océan, et les grandes questions de la Géologie moderne, invitent les naturalistes voyageurs à diriger leurs recherches sur les points suivans :

Recueillir de l'eau de mer partout où l'on aperçoit à la surface des changemens de couleur et de densité, en forme de pellicules, de stries et de taches huileuses. Dans ces parages on est sûr de trouver abondance d'animaux microscopiques, et comme il est prouvé par l'expérience que ces petits êtres, même les infusoires pélagiques, peuvent, soit à cause de leurs carapaces siliceuses, soit à cause de la consistance de leurs membranes ou tissus organiques, être examinés sous le microscope, après avoir été conservés pendant plusieurs années, on tâchera, j'espère, de les recueillir de deux manières. Là où l'on voit les stries de différentes couleurs, l'on enlèvera une portion de ces stries, en enfonçant dans l'eau de mer des lames très-minces de mica, ou du papier bien fort. Ces lames de mica, ou ces feuilles de papier seront soulevées horizontalement ; on les séchera et les conservera dans un livre, les animaux restant attachés aux mêmes lames de mica ou feuilles de papier, au moyen desquelles on les a recueillis. Dans les parages où l'eau de la mer paroît entièrement pure et presque incolore, elle renferme souvent des acalèphes, des crustacées, et des infusoires microscopiques. Il s'agit seulement de pouvoir examiner ces eaux dans un état pour ainsi dire concentré, d'enfermer les êtres vivans dans un moindre volume du fluide. À cet effet, M. Ehrenberg a l'habitude de faire puiser de l'eau à la surface de la mer dans un seau, et de la faire filtrer ou passer à travers un linge très fin, de manière que chaque fois on sépare la portion concentrée qui n'a pas encore pénetré entièrement à travers le filtre. Ces portions concentrées (plus riches en animaux invisibles à l'œil nu) sont conservées dans de petits flacons de 2 ou 3 pouces de haut. On laisse quelques bulles d'air entre le bouchon et l'eau. Si pendant l'opération de la filtration, on découvre quelques acalèphes visibles à l'œil nu, il faudra les séparer et les placer dans l'esprit de vin, afin que ces petites masses gélatineuses n'altèrent pas l'eau de mer concentrée.

Comme ces opérations sont extrêmement faciles, il est à désirer que pendant toute l'expédition, par différens degrés de latitude et de longitude, on recueille de l'eau de mer surtout là où les algues marines abondent. Par les moyens qu'on vient de proposer, on parviendroit à étendre d'une manière inattendue la connaissance de la nature intime des petites organisations et de leur distribution géographique sur le globe. Il ne faut pas oublier que les estomacs remplis de carmin et d'indigo dans tous les Polygastres, que les yeux dans les Rotifères et *l'Eudorina elegans*, et les dents des Hydatines, se conservent pendant de longues années, lorsque ces êtres

microscopiques sont préparés entre des lames de mica d'après la méthode de M. Ehrenberg.

Recueillir les animaux qui causent la phosphorescence de l'océan, phosphorescence dans laquelle le *Mammaria scintillans* semble jouer le rôle principal, avec d'autres acalèphes et des infusoires pélagiques (espèces de Peridinium, de Synchæta et de Prorocentrum). Observer si la phosphorescence n'est pas plus générale et plus fréquente par un ciel couvert et d'apparence orageuse: examiner si pendant la phosphorescence générale de l'Océan *l'Æquorea forskoeliana*, *A. phosphorifera*, le *Pelagia cyanella*, *P. noctiluca* et *P. pancpyra*, luisent par scintillation c. à. d. non d'une manière continue, mais en donnant des étincelles par la décharge spontanée de certains organes électriques cellulaires; conserver ces acalèphes et les béroés phosphoriques dans l'esprit de vin; examiner si certaines espèces de poissons, *Chimæra arctica*, *Clupea erythræa*, *Coryphæna hippuris* et *Scomber pelamys*, sont phosphorescentes par elles-mêmes, ou si ce n'est pas plutôt par l'adhérence d'infusoires phosphorescens.

Recueillir partout celles des substances minérales qui selon les découvertes de M. Ehrenberg, sont composées d'infusoires fossiles comme le tripoli, les schistes à polir, les semi-opales, les minérais de fer limoneux riches en *Galionella ferruginea*, les dépôts colorés des sources salées ou ferrugineuses, les craies, les silex pyromaques, les marnes alternant avec la craie, les dépôts siliceux, les terres que mangent quelques peuples, par goût ou par besoin. Quoique les infusoires à carapaces siliceuses, plus indifférens aux variations des latitudes et des climats, ayent manifesté généralement plus d'aptitude à résister aux grands cataclysmes géologiques, plusieurs des bryozoa calcaires ou polythalames de la craie existent cependant aussi vivans dans la mer actuelle. M. Ehrenberg en a récemment trouvé de vivans dans la mer Baltique, identiques avec des polythalames enfouies dans les craies et leurs marnes. Cette circonstance d'identité donne, à cause de l'âge des formations craieuses, un vif intérêt géologique à ce genre d'investigations.

Recueillir et conserver avec soin, à cause des petites organisations qu'ils renferment, les sables des dunes, les sables de toutes les côtes que l'on visite, les sables rejetés par les hautes marées, les sables qui s'attachent à la sonde et à l'ancre des vaisseaux; recueillir des échantillons des terres qui composent les marais et des endroits inondés et desséchés. Les plus petites quantités suffisent, en marquant bien exactement les localités où elles ont été recueillies.

VI. Botanique.

Plantes marines qui vivent en société.

Il reste des doutes, si dans certains parages (comme au banc d'algues anciennement connu près des Iles Azores) le *Fucus natans* (*Sargassum vulgare* et *S. bacciferum*, Agardh) continue à végéter sans racines, en flottant à la surface de l'Océan au gré des vents et des courans, ou si le Fucus, récemment arraché à des rochers dont on suppose l'existence et la proximité, ne peut conserver son état de

fraîcheur que pendant un très court espace de tems. Les ingénieuses considérations de M. Charles Darwin (Journal, pp. 303—305), ont répandu un nouvel intérêt sur ces "great aquatic forests." L'analogie des Vaucheries et du *Polysperma glomerata*, la facilité même avec laquelle, dans l'eau douce, des plantes phanérogames (l'*Aldrovanda vesiculosa*, et des branches du *Najas major*) continuent à végéter, lorsqu'elles nagent dépourvues de racines, ont fait croire à un voyageur d'une instruction très-variée, M. Meyen, que le *Fucus natans* peut pousser des feuilles (frondes), sans racines et sans adhérence au fond, mais que dans ce cas, le *Fucus natans* flottant ne porte jamais de fruits. Recueillir les échantillons de Fucus qui se sont développés en forme arrondie, les branches s'étendant comme par rayons. Mesurer la température de l'eau la plus froide dans laquelle végètent ces plantes sociales.

(Signé) ALEXANDRE DE HUMBOLDT.

Berlin, le 26 *Octobre*, 1839.

Letter from Professor A. Erman to Major Sabine, R.A., F.R.S.

MONSIEUR, A' Berlin, le 12 Nov. 1839.

J'ai eu le plaisir de vous exprimer à Berlin mon vif intérêt pour l'expédition magnétique, dont votre rapport sur l'intensité totale (*Seventh Report of the British Association for the Advancement of Science*) a fait concevoir le plan, et que le gouvernement Anglais a mis en œuvre avec une munificence entièrement digne du sujèt. Vous savez combien je félicite les voyageurs qui continueront jusqu'aux plus hautes latitudes Australes, les observations que je n'ai poussées que peu au delà du parallèle du Cap Horn, et qui vont tout autant préciser la forme et la position des lignes magnétiques de cet hémisphère, que nous avons pu le faire, M. Hansteen et moi, pour celles de l'Asie du Nord où tout conspiroit à favoriser notre entreprise. Aussi est ce avec beaucoup de reconnoissance que j'accepte l'entremise que vous avez bien voulu m'offrir, pour signaler aux membres de cette grande expédition, quelques résultats et quelques sujets de recherche, que notre voyage pour un but analogue me porte à recommander à nos successeurs. Il est vrai que la belle instruction dont la Société Royale a muni ses voyageurs, leur indique très complètement les moyens d'obtenir, tant sur mer que lors des mouillages aux côtes et aux glaces polaires, une série continue de déterminations des trois élémens magnétiques. Elle est si riche en détails importans que, dans l'intérêt de la science, on ne sauroit rien desirer au-delà du stricte accomplissement de ce plan de voyage. Cependant pour toujours soutenir l'attention et le zèle dans un travail uniforme d'aussi longue durée, et pour les faire redoubler à point

nommé, dans les endroits où les observations augmentent d'importance, il n'y a je crois rien de plus efficace, qu'une comparaison suivie des résultats de l'observation, d'une part avec ceux de la théorie qu'il s'agit de perfectionner, et de l'autre avec les évaluations purement empiriques de ses prédécesseurs. L'expédition antarctique doit jouir de cet avantage pour ses mesures d'intensité totale, en se servant de la carte isodynamique construite d'après la théorie de M. Gauss, et de celle que vous avez directement établie sur les résultats des voyageurs*. J'ai destiné aux mêmes fins la carte ci jointe, Pl. III., représentant *les lignes d'égale déclinaison pour une époque entre* 1827 *et* 1830. Je les ai obtenues par une interpolation graphique, et devant fournir des isogones indépendantes de toute vue de théorie. J'ai noté sur la carte même les résultats numériques qu'elle représente, et il ne me reste ici qu'à mentionner les voyageurs qui les ont fournis, la direction des routes qu'ils ont suivies, et l'époque de leurs observations.

I. *L'Europe et l'Asie septentrionales.*

MM. *Hansteen* et *Due*, de *Christiania* à *Irkuzk* et à l'embouchure du *Jenisei*, en 1828 et 29.
Erman, de *Berlin* aux bouches de *l'Obi*, par *Irkuzk* et *Ochozk* au *Kamtschatka*, en 1828 et 29.

II. *Le Grand Océan.*

Le Capit. *Lütke* (sur la Corvette le *Siniavine*), du *Cap Horn*, par *Valparaiso*, les iles de *Sitka* et *d'Ounalaska*, à *Petropawlowsk*, en 1827.
Idem (*idem*) de *Petropawlowsk* à *Manilla*, en 1828.
Erman (la Corvette le *Krotkoi*), de *Petropawlowsk*, par *Sitka*, *San Francisco*, et *Otaheite*, au *Cap Horn*, en 1829 et 30.

III. *L'Atlantique.*

Le Capit. *Lütke* (le *Siniavine*) de l'ile de *Teneriffe*, par *Rio Janeiro*, au *Cap Horn*, en Décembre 1826, et 1827.
Idem (*idem*) du *Cap de Bonne Espérance*, par les iles de *St. Helène* et de *Fayal*, au *Canal Anglais*, en 1829.
Erman (le *Krotkoi*), du *Cap Horn*, par *Rio Janeiro*, à *Portsmouth*, en 1830.

IV. *La mer des Indes.*

Le Capit. *Hagemeister*, (la corvette le *Krotkoi*), du *Cap de Bonne Espérance*, à *Port Jackson*, en 1828.
Lütke (le *Siniavine*), de *Manilla*, au *Cap de Bonne Espérance*, en 1829.

Je n'ai du ajouter à ces résultats presque contemporains (Dec. 1826 à Oct. 1830) qu'une dixaine d'observations antérieures, toutes faites dans la mer glaciale du Nord, et nommèment par le Capitaine *Wrangel* dans la partie orientale de cette mer (68° à 70° lat., 162° à 182° à l'Est. de Green.) en 1823, et par

* Pl. I. and II.

Le Capitaine *Lütke* dans sa partie occidentale (70° à 77° lat., 27° à 52° à l'Est de Green.) en 1821.

Si l'on compare maintenant dans leur ensemble ce tracé immédiatement calqué sur les observations, et la carte que la théorie de M. *Gauss* a fournie pour la même époque, Pl. IV., on sera frappé de leur accord éminemment satisfaisant, tant pour les formes que pour les places qu'elles assignent à la plûpart des isogones. On envisagera toutefois, comme prévues d'avance, des courbures plus accidentées et moins arrondies dans les isogones empiriques : résultats nécessaires tant d'une interpolation imparfaite d'observations affectées d'erreurs, que d'influences locales, telles que la différente constitution géologique des pays et leurs accidens de climat ; car la théorie que son illustre auteur ne présente que comme une ébauche, ne saurait déja reproduire ces effêts de causes secondaires. Mais, indépendamment de ces écarts accidentels et locaux, une comparaison suivie des deux cartes fait ressortir entre elles quelques différences plus décidément prononcées, portant sur de grandes portions d'isogones bien établies par l'observation. Je me permèts de les signaler ci-après à l'attention de vos voyageurs.

§ 1. Entre 0° et 150° E.

1. *Les sommèts concaves des isogones negatives (orientales) que la carte empirique place vers 77° E., y atteignent de moindres latitudes que d'après la théorie.*

Nommément:

		Sur la carte empirique.	Sur la carte de M. Gauss.
L'isogone de	— 15° descend jusqu'à	65° lat.	78° lat.
„	— 10° „	58° 5′	64°

2. *Le système de déclinaison positive ou occidentale, qui a son centre d'après l'interpolation graphique vers 130° E., et d'après M. Gauss àpeine 0°·3 à l'ouest de ce même méridien, s'écarte de la théorie par la valeur des lignes qui le composent, et cette différence est l'inverse de la précédente.*

Les sommèts convexes de ces lignes sont,

		Sur la carte empirique.	Sur la carte de M. Gauss.
Pour la courbe de	0° à	68°·5 lat.	61°·7 lat.
„ „	+ 2°	65°	54°
„ „	+ 6° vers	61°	n'existe pas, le centre

du système situé en 45° lat. ne devant avoir que + 2° 30′ déclin.

On résumera ces deux circonstances, en observant qu'un voyage depuis 65° lat. et 77° E. long. jusqu'en 61° lat. et 130° E. long. offre en réalité un plus fort changement de déclinaison que suivant la théorie. En effêt le changement observé serait de 21° (depuis — 15° jusqu'à + 6°) où la théorie ne demande que 10° (depuis — 10° jusqu'à 0°).

3. *La différence des deux cartes relative à la ligne sans déclinaison entre les dits méridiens n'est au fond qu'une suite de ces deux circonstances (Nos. 1 et 2).* La branche occidentale de cette courbe,

sur laquelle la théorie et l'observation sont presque d'accord, et que cette dernière fait passer par 50° lat. et 48° E. long., se distingue sur les deux cartes par son prolongement vers le Sud et le Sud Est. Elle a son sommet concave sur la carte empirique en —1° lat. et sur la carte de M. Gauss vers —10°·2 lat. (les latitudes australes étant pris négatives), et passé ce terme, d'après l'observation directe, la courbe se relève vers le Nord Est et le Nord, embrasse le système Asiatique de déclinaison occidentale, pour ne se replier qu'après, par la mer d'Ochozk, le Grand Océan, et la mer des Indes, sur la nouvelle Hollande. La théorie lui assigne au contraire, d'abord après le sommet concave, un rebroussement vers le Sud (en 105° E.), qui la porte directement sur la nouvelle Hollande; aussi voit on sur la carte de M. *Gauss*, le susdit système de déclinaison occidentale, entouré d'une courbe à zéro fermée et isolée, et dont la branche orientale se trouve plus à l'ouest que ne le demandent les observations pour la partie correspondante de la ligne continue.

En effet ces parties correspondantes de la courbe à zéro coupent:

	Sur la carte empirique.	Sur la carte de M. Gauss.
Le 60° lat.	sous 150° E.,	sous 140° E.
50° „	151°·3 E.	„ 147°·8 E.

Mais je suis loin d'attribuer une spécialité d'intérêt à l'*isogone de zéro*;—la différence de deux branches isolées, à une courbe continue, que nous venons de lui trouver sur les deux cartes, ne me parait au contraire ni plus ni moins grave, que si elle portait sur quelque autre courbe de ce genre. Je crois plutot que pour voir cet écart dans son vrai jour, il faudra observer que dans le système en question, la valeur limite entre des courbes isolées et des courbes continues est, *suivant la théorie* de — 1° 14′ *déclin. orientale*, tandis que *l'observation parait l'élever* à une *déclin. occidentale* de + 1°, ou environ, car pour dériver de données numériques la *valeur précise* de cette *limite*, il ne suffit ni d'une interpolation graphique ni d'aucun moyen différent d'une théorie complète. J'observe en outre, et pour me prémunir contre plus de responsabilité que je ne dois avoir sur ce point, que la dite partie de ma carte repose uniquement sur les observations suivantes de M. *Lütke.*

Longit.	Latitude.	Déclinaisons d'après: M. Lütke. L.	Déclinaisons d'après: La théorie. T.	L—T.
135° 34′	+ 14° 35′	+0° 10′	— 1°·25	+ 1°·4
134 38	+ 15 34	+0 4	— 1	+ 1·1
134 04	+ 16 4	+1 2	0	+ 1·0
122 33	+ 19 54	+2 20	+0·2	+ 2·1
117 53	+ 13 41	+0 33	— 0·8	+ 1·3
115 21	+ 13 4	+0 23	— 0·8	+ 1·2
113 03	+ 12 41	+0 33	— 1·4	+ 2·0
105 04	— 8 39	+1 26	— 0·4	+ 1·8
105 32	— 9 46	+1 0	— 0·2	+ 1·2

Malgrè leur grande influence sur la forme de la courbe à zéro, ces différences entre la théorie et l'observation sont donc beaucoup plus foibles que celles observées dans les contrées précitées (Nos. 1 et 2) et qui s'élevaient respectivement à — 5° et à + 6°.

Les parties australes des deux cartes situées entre les dits méridiens de 0° à 150° E, s'accordent très bien entre elles.

§ 2. Depuis 150° jusqu'à 360° E.

Il en est de même dans l'hemisphère boréal, depuis 162° jusqu'à 262° E., pour les isogones de —30°, à —15°; mais passé ce terme les courbes théoriques de —12°, de —10°, etc. portent les déclinaisons orientales qu'elles expriment jusqu'à de moindres latitudes boréales que ne l'indique l'observation. Ainsi

	Sur la carte empirique.	La carte de M. Gauss.
L'isogone de — 12° descend jusqu'à	33°·5 lat.	23° lat.
„ „ 6° „ „	28°·5	17°

C'est cette circonstance, et une toute pareille pour les isogones de même nom dans l'hemisphère austral, qui produisent

4. *Une diversité des deux cartes relativement au système fermé de déclinaison orientale dans le Grand-Océan.*

Les courbes de — 10°, — 9°, et — 8° sont les parties de ce système que l'observation directe a le mieux reconnues, et nous trouvons à *chacune d'elles* plus d'étendue dans le sens du méridien que ne l'adopte la théorie. Ainsi d'après

		La carte empirique.	La carte de M. Gauss.
L'isog. de — 10° va	depuis	+ 27°·8 lat.	+ 17° lat.
	jusqu'à	— 49°·5	— 39
„ — 9° „	depuis	+ 25	+ 12°·5
	jusqu'à	— 47	— 36
„ — 8° „	depuis	+ 23	+ 7°·5
	jusqu'à	— 44°·5	— 34°

Leurs diamètres dans le sens du méridien sont donc respectivement:

d'après *l'observation directe* de 77°·3, 72° et 67°·5,
et d'après *l'interpolation théorique* de 56°, 43°·5 et 41°·5.

Les observations nous apprennent en outre sur les isogones de ce système, que celle de—10° passe bien décidément d'un pole nord à un pole sud, et qu'au contraire la courbe de —8° est *isolée et rentrante.* L'isogone de —9° participe tellement aux propriétés de ces deux espèces de courbes, que, parmi celles que représente ma carte, elle doit être la plus voisine de la valeur limite. La théorie s'y accorde très bien en indiquant —8° 46'·5 pour cette même limite. L'accord des deux cartes est moins parfait sur la position du centre de ce système et sur la déclinaison qui y règne, car la forme des courbes empiriques de—10° à—7° engagerait à le présumer situé

vers 231°·8 E.
—12° lat.

tandis que l'interpolation théorique le porte en

219°·8 E.
—14°·5 lat.

aussi la théorie attribue à ce point une *déclinaison minimum* de —5° 15', mais nous avons très souvent observé sur le Krotkoi, de même que Mr. Lütke sur la route plus orientale du Siniavin, des déclinaisons entre —5° et —4° et mêmes quelques unes de —3° 50' à —3° 40'. Nous étions cependant encore très sensiblement eloignés du centre des courbes.

5. *Dans l'hemisphère austral entre les méridiens de* 192° E. *et* 262° E. *les isogones de* —12° *et de* —15°, *d'après la théorie ne s'approcheraient du pole austral que jusqu'aux paralleles de* —38°·8 *et de* —49°, *tandis que les observations paraissent les y étendre jusqu'en* —52°·7 *et* — 58°.

Mais je termine cette comparaison, en vous priant, Monsieur, d'accorder encore votre attention à l'harmonie très parfaite des deux cartes relativement au système de déclinaison occidentale qui recouvre l'Atlantique et l'Europe, lequel, vu la grande fréquence des observations dans ces parages, est un des plus solidement établis par l'expérience directe. La théorie porte la *valeur limite pour ce système* à +22° 13', et les observations démontrent, d'abord, que cette même valeur est comprise entre +20° et +25°; et de plus, qu'elle est beaucoup plus rapprochée de la moyenne arithmétique de ces deux nombres, que d'aucun d'eux.

Je passe à quelques autres sujets de recherche que je me permets de résumer en de simples questions:

Aurores Polaires. Y a-t-il dans les hautes latitudes antarctiques quelque indication d'une duplicité d'Aurores Polaires? Les habitans de *Bérésow* sur l'Obi (63° 56' N. lat.) en distinguent en effèt de deux espèces: de plus foibles ayant leurs centres à l'Ouest; et de plus brillantes qui se forment à l' Est du meridien. Les données que j'ai pu recueillir sur les azimuts où se formeraient ces deux phénomènes m'ont fait présumer qu'ils surgissent respectivement de l'un ou de l'autre des deux foyers magnétiques de l'hemisphère boréal.

Phosphorescence de la mer. Existe-t-il un minimum de température qui empècheroit d'avoir lieu le développement de lumière opéré par des Méduses, des Scolopendres, et surtout par des Crustacés microscopiques vaguement qualifiés de Zoophytes infusoires?

J'ai observé des phases très brillantes de ce phénomène sur la mer d'Ochozk dans les nuits du

3 *Aout*	par	+39°·2 F.	température de la mer.
5 *Aout*	„	+41 ·0	„
6 *Aout*	„	+41 ·2	„
7 *Aout*	„	+46 ·6	„

mais il y eut cessation parfaite la nuit du 4 *Aout* où la température de la mer baissa jusqu' à +37°·4 F.

Un phénomène lumineux, différent d'apparence et d'origine, s'observe sur la même mèr d'*Ochozk* à l'approche de la saison froide, et y est connu sous le nom de *Spolochi*. Ce sont des bandes lumineuses,

qui paraissent douées d'un mouvement propre, et qui se repandent en jets rayonnans, depuis un centre commun à plusieurs d'entr'elles et également situé à la surface de la mer. On ne saurait les confondre avec la lumière due aux Mollusques, laquelle ne forme jamais des bandes, mais des points distinctement isolés, et brillans de préférence dans le sillage du vaisseau, dans les brisans, et sur l'écume des lames et des vagues. Les bandes en question ressemblent au contraire à de la lumière électrique qui se répandrait à la surface d'un conducteur imparfait. *Y a-t-il des phénomènes analogues dans l'hemisphère austral, et quelles circonstances paroissent les provoquer?*

Météorologie.

A égalité de latitude, la moyenne hauteur du baromètre m'a paru moindre sur le grand Océan que sur la mer Atlantique : *la même différence s'observe-t-elle encore sur les prolongemens des méridiens en question jusqu'à de hautes latitudes Antarctiques?*

Sur le grand Océan, entre le 50° et 60° de latitude nord, c'est bien décidément le *vent d'Ouest* qui augmente la pression atmosphérique au dessus de la valeur moyenne. Cet effet du *vent d'Ouest* est le contraire de ce que l'on observe en Europe, et il me parait fort intéressant de recueillir sur ce point des données correspondantes dans l'hémisphère austral.

J'ai vu avec beaucoup de plaisir que la Société Royale dirige l'attention de ses voyageurs sur la différence de la colonne barométrique aux limites polaires et aux limites équatoriales des zones alizées. Voici les résultats que j'ai obtenus à cet égard de mes propres observations. (*Poggendorf, An. der Physik für* 1831.)

Mois.	Longit.	Alizé N.E. Diff. des haut barom.	Mois.	Longit.	Alizé S.E. Diff. des haut barom.
Mai et Juin..	167°	3'''·154	Mai	179°	2'''·245
Janvier	233	0 ·929	Jan. et Fev.	222	2 ·714
Juil. et Août..	327	3 ·016	Juin et Juil.	324	2 ·453
Novembre ..	342	2 ·668	Decembre..	333	1 ·492

Les différences sont exprimées en *lignes* du *pied de Paris*, et se rapportent aux colonnes barométriques observées à la limite polaire et à la limite équatoriale de la zone alizée.

Essuie-t-on jamais des orages sur mer quand on est à la fois à une grande distance de toute côte, et loin des limites des alizés? L'expérience d'une seule année ne m'en a fourni aucun exemple.

Etoiles filantes.

Si les voyageurs antarctiques ont le loisir d'observer le retour périodique des étoiles filantes du 10 Août ou du 13 Nov., il seroit fort à desirer qu'ils fissent attention à la direction apparente de leur mouvement, et que nommément ils dessinassent sur une carte céleste leurs trajectoires apparentes, pour examiner après, si *leurs*

prolongemens se coupent en un même point du ciel. Les étoiles tombantes de 1839, Août 10, convergeaient toutes vers le point du ciel:

Ascens. droite 222°·4
Declinaison .. 51°·2 Australe.

L'instruction de la Société Royale ayant dirigé l'attention des voyageurs sur la *Chionis Alba,* je me permets de leur communiquer que nous avons pris dans deux jours consécutifs 5 ou 6 de ces oiseaux, en nous trouvant à la hauteur des *iles Falklands,* et à une distance de 48 à 60 milles marins de leur extrémité orientale. Il est vrai que ce fut par un vent *d'ouest assez frais,* mais on ne saurait cependant décider sans recherche ultérieure, si ces oiseaux intéressans ne sont pas engagés par quelque autre cause à s'éloigner des côtes qu'ils habitent. Les *Chionis* nous ont paru si propres à la domesticité que l'on pourrait sans doute es conserver vivantes jusqu'au retour en Europe, et peut être même en faire propager l'espèce. Il est fort probable qu'ils se nourrissent de préférence de grains ou d'autres semences dures, car nous leur avons constamment trouvé dans l'estomac du sable et de petits cailloux, que nous croyions destinés à faciliter la trituration et la digestion de pareilles substances.

Je termine ces remarques detachées en me recommendant, Monsieur, à l'indulgence que vous daignates si souvent témoigner à

Votre très devoué serviteur,

M. le Major Sabine, R.A. — A. ERMAN.

Comparisons made at the Royal Society's Apartments, Somerset-House, on the 16th, 17th, 19th and 20th of August, 1839, with the Royal Society's Standard, of the Marine, Standard, and Mountain Barometers supplied to the Antarctic Expedition, and to the four fixed Magnetic Observatories of Canada, Cape of Good-Hope, St. Helena, and Van Diemen's Land: by J. D. Roberton, Assist. Sec. Royal Society.

Royal Society's Standard.			Marine Barom., No. 19. M.		Marine Barom., No. 20. M.		Standard, No. 31.		Standard, No. 32.		Standard, No. 33.		Standard, No. 34.	
Barom. Flint Glass.	Barom. Crown Glass.	Att. Ther.	Barom.	Att. Ther.	Barom.	Att. Ther.	Barom.	Att. Ther.	Barom.	Att. Ther.	Barom.	Att. Ther.	Barom.	Att. Ther.
30·014	30·006	70·2	29·972	62·4	29·986	62·7	30·006	66·2	30·000	62·8	30·010	63·2	30·004	65·3
29·930	29·926	66·7	29·902	62·7	29·904	65·2	29·918	66·0	29·916	62·8	29·918	63·2	29·918	65·7
29·696	29·690	62·7	29.676	61·7	29·686	62·3	29·688	63·7	29·686	62·0	29·688	62·0	29·686	63·6
29·654	29·650	71·2	29·614	62·4	29·616	62·9	29·642	66·4	29·634	62·7	29·642	63·2	29·640	65·3
29·634	29·630	67·0	29·610	63·3	29·618	63·4	29·632	66·8	29·620	64·3	29·632	63·7	29·628	66·7
29·670	29·666	64·5	29·628	62·3	29·648	62·6	29·661	65·0	29·662	62·6	29·664	62·7	29·666	64·8
29·712	29·704	66·2	29.676	63·2	29·684	63·3	29·708	66·2	29·700	63·2	29·708	63·3	29·712	65·8
30·080	30·072	60·2	30·020	60·4	30·040	60·7	30·066	60·9	30·068	60·6	30·066	60·7	30·078	60·6

Comparisons of Mountain Barometers corresponding with the above Standards.

Mountain, No. 31.		Mountain, No. $\frac{32}{1}$.		Mountain, No. 33.		Mountain, No. 34.	
29·972	65·6	29·974	65·8	29·998	62·3	29·990	65·3
29·892	66·2	29·888	66·0	29·920	62·5	29·908	65.7
29·660	64·0	29·664	64·2	29·674	61·6	29·692	64·8
29·614	65·7	29·622	65·8	29·622	62·3	29·636	65·4
29·598	66·8	29·612	66·8	29·620	62·8	29·620	66·6
29·638	65·0	29·642	65·3	29·652	62·2	29·656	64·9
29·674	66·3	29·686	66·5	29·690	62·7	29·696	66·0
30·028	60·9	30·032	61·0	30·040	60·2	30·048	60·9

Comparisons made at the Royal Society's Apartments, Somerset-House, in August 1839.

Royal Society's Standard Barometer.			Major Sabine's, (Round).		Major Sabine's, (Flat).	
Flint Glass.	Crown Glass.	Att. Ther.	Barom.	Att. Ther.	Barom.	Att. Ther.
29·634	29·630	67·0	29·578	66·8	29·590	66·8
29·670	29·666	64·5	29·616	65·4	29·616	65·0
29·712	29·701	66·2	29·662	66·5	29·654	66·3
30·080	30·072	60·2	30·012	61·3	30·006	60·9

Captain J. C. Ross's Instruments.

Standard Barometer, No. 32.		Mountain Barom., No. 32. (1.)		Mountain Barom., No. 32. (2.)	
29·620	64·3	29·612	66·8	29·612	63·3
29·662	62·6	29·642	65·3	29·642	62·3
29·700	63·2	29·686	66·5	29·676	63·2
30·068	60·6	30·032	61·0	30·028	60·3

Comparisons made in March, 1840.

Royal Society's Standard.			Standard, No. 46.		Mountain, No. 41. Capt. Ross.		Mountain, No. 45. Capt. Ross.		Mountain, No. 46. Lt. Wilmot.		Mountain, No. 47.	
Barom. Flint Glass.	Barom. Crown Glass.	Att. Ther.	Barom.	Att. Ther.	Barom.	Att. Ther.	Barom.	Att. Ther.	Barom.	Att. Ther.	Barom.	Att. Ther.
29·661	29·656	46·3	29·678	46·3	29·646	46·2	29·652	47·4	29·690	46·8	29·662	46·4
29·726	29·718	48·5	29·728	46·2	29·676	46·3	29·672	47·4	29·708	46·9	29·684	46·6
30·024	30·016	47·9	30·028	49·6	29·962	49·0	29·952	50·2	29·986	49·5	29·966	49·2
30·266	30·258	45·6	30·268	43·8								

Comparisons of Standards with the Royal Society's, made for the Honourable the East India Company, in April 1840.

Royal Society's Standard.			Standard, No. 48.		Standard, No. 49.	
Barom. Flint Glass.	Barom. Crown Glass.	Att. Ther.	Barom.	Att. Ther.	Barom.	Att. Ther.
30·408	30·400	48·2	30·426	45·7	30·400	45·9
30·368	30·360	47·8	30·380	46·6	30·364	46·6
30·346	30·338	48·0	30·356	47·0	30·340	47·0
30·258	30·250	50·0	30·274	46·2	30·250	46·3
30·134	30·128	48·8	30·150	47·8	30·130	48·0
29·918	29·912	49·2	29·938	48·7	29·924	48·8

Comparisons made with the Royal Society's Standard, of various Standard and Mountain Barometers, for the Honourable the East India Company, (made in February, 1840.)

Royal Society's Standard.			Standard, No. 37.		Standard, No. 38.		Standard, No. 40.		Standard, No. 41.		Standard, No. 42.		Standard, No. 43.	
Barom. Flint Glass.	Barom. Crown Glass.	Att. Ther.	Barom.	Att. Ther.	Barom.	Att. Ther.	Barom.	Att. Ther.	Barom.	Att. Ther.	Barom.	Att. Ther.	Barom.	Att. Ther.
30·450	30·442	37·9	30·458	38·6	30·440	38·4	30·466	38·7	30·458	38·4	30·458	38·0	30·456	38·8
30·450	30·444	37·6	30·456	38·2	30·442	37·9	30·468	38·5	30·458	37·9	30·458	37·7	30·452	38·4
30·458	30·450	37·2	30·460	38·0	30·454	38·2	30·468	38·5	30·468	38·0	30·462	37·5	30·458	38·4
30·452	30·446	36·6	30·456	37·2	30·452	37·0	30·472	37·3	30·[illegible]64	37·[illegible]	30·458	36·7	30·452	37·2
30·434	30·426	36·9	30·438	37·3	30·428	37·5	30·452	37·7	30·444	37·3	30·436	37·0	30·436	37·6

Comparisons of Mountain Barometers corresponding with the above Standards.

Mountain, No. 40.		Mountain, No. 41.		Mountain, No. 42.		Mountain, No. 43.		Mountain, No. 44.	
30·380	38·6	30·438	38·9	30·350	38·8	30·426	38·8	30·424	39·0
30·392	38·2	30·432	38·4	30·348	38·3	30·432	38·3	[illegible]0·426	38·6
30·390	37·8	30·432	38·2	30·346	38·2	30·340	38·4	[illegible]·422	38·3
30·390	36·9	30·432	37·5	30·350	37·2	30·438	37·3	30·426	37·4
30·384	37·0	30·420	37·6	30·432	37·4	30·424	37·5	30·418	37·6

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FORMS FOR BOOKS.

.... day, the ... of | OBSERVATORY at (........)
..... 18.. | Daily Observations of MAGNETOMETERS,

	Gott Mean Time.	Mean Time at Observ.	DECL MAGNETOM. Readings.	DECL MAGNETOM. mean.	HORIZ. FORCE MAGNETOM. Readings.	HORIZ. FORCE MAGNETOM. mean	HORIZ. FORCE MAGNETOM. Therm.	VERT. FORCE MAGNETOM. Readings.	VERT. FORCE MAGNETOM. mean.	VERT. FORCE MAGNETOM. Therm.
	A	a								
	B	b								
	C	c								
	D	d								
	E	e								
	F	f								
	G	g								
Triple Observⁿ.*	H'	h'	2		3			1		
Triple Observⁿ.*	H	h	5		6			4		
Triple Observⁿ.*	H"	h"	8		9			7		
	I	i								
	K	k								
	L	l								
	M	m								

FORM No. 1.

* *As the days commence with the Magnetic hour nearest after* 12 *midnight* of the place, *the time of the triple Observation will be different at each observatory, and cannot therefore be printed.*

OBSERVATORY at ( ) day, the of
and METEOROLOGICAL INSTRUMENTS. 18

Mean Time at Observ.	BAROMETER. Height.	Temp. of Merc.	THERMOM. Dry.	Wet.	ELECTROM.		Temp. Dew Point.	
a								
b								
c								
d								
e								
f								
g								
h								
i								
k								
l								
m								

State of the Weather.

a	Note
b	
c	
d	
e	
f	
g	
h	
i	
k	
l	
m	
9 A.M.	Temper. Max. ( ) Min. ( )
9 A.M.	Radiation Sol. ( ). Terr ( ).

Form No. 1.

OBSERVATORY at (———————) ——— day, the —— of
Term day Observ^ns of MAGNETOMETERS, &c. ——————— 18__

Specification of Magnetometer.	Times of Observation.		MAGNETOMETER.		Times of Observation.		MAGNETOMETER.	
	Gott. M.T.	M.T. at Observ.	Readings.	mean.	Gott. M.T.	M.T. at Observ.	Readings.	mean.
	10PM m. s.	m. s.			10PM m. s.	m. s.		
Declination	0:00				30:00			
Horizontal Force	2:30				32:30			
Declination	5:00				35:00			
Vertical Force	7:30				37:30			
Declination	10:00				40:00			
Horizontal Force	12:30				42:30			
Declination	15:00				45:00			
Vertical Force	17:30				47:30			
Declination	20:00				50:00			
Horizontal Force	22:30				52:30			
Declination	25:00				55:00			
Vertical Force	27:30				57:30			

Hour of Gott. Mean Time.	THERMOMETERS.				BAROMETER.		ELECTROM.		
	H.F.	V.F.	Dry.	Wet.	Height.	Temper.			
10PM									
	Weather.								

Form No. 2.

OBSERVATORY at (__________)

Abstract of daily Observations made during the Month of ______ 18__

Date.	(NAME OF INSTRUMENT.) a	b	c	d	e	f	g	h	i	k	l	m	Sums.
Sums													
Means													

FORM No. 3.

OBSERVATORY at (______________)

Abstract of daily Observations made during the Month of______ 18__

Date.	Temp. of Dew Point.				Elast. of Vapour.				Temperat.		Radiation		Moon's Age.
	3 A.M.	9 A.M.	3 P.M.	9 P.M.	3 A.M.	9 A.M.	3 P.M.	9 P.M.	Max.	Min.	Solar.	Terr.	
Sums													
Means													

Form No. 4.

OBSERVATORY at (______________)

Abstract of triple Observ. made during the Month of _ 18__

Date	V F MAGNETOM			DECL MAGNETOM			H F MAGNETOM			
Sums										
Means										

FORM No. 5.

The Sums and Means of the triple Observations are not required; they have been included in this form, of which a portion is blank to admit of the insertion if necessary, of other observations in the same page.

Form No. 6.

OBSERVATORY at (____________) ____________ day, the ____ of ____________ 18 ____

Abstract of Term-day Observations

Gott Mean Time.	DECLINATION MAGNETOMETER.											
	10 PM	11.	Midn.	1 AM.	2.	3.	4.	5.	6.	7.	8.	9 AM.
m. s. 0:00												
5:00												
10:00												
15:00												
20:00												
25:00												
30:00												
35:00												
40:00												
45:00												
50:00												
55:00												
	10 AM	11.	Noon.	1 PM.	2.	3.	4.	5.	6.	7.	8.	9 PM.
m. s. 0:00												
5:00												
10:00												
15:00												
20:00												
25:00												
30:00												
35:00												
40:00												
45:00												
50:00												
55:00												

Form No. 7.

OBSERVATORY at (____________________)______________day, the____of
Abstract of Term-day Observations ____________________________ 18__

HORIZONTAL FORCE MAGNETOMETER.

Gott. Mean Time.	10 PM	11.	Midn.	1 AM.	2.	3.	4.	5.	6.	7.	8.	9 AM.
m. s. 2:30												
12:30												
22:30												
32:30												
42:30												
52:30												
Therm.												

	10 AM	11.	Noon.	1 PM.	2.	3.	4.	5.	6.	7.	8.	9 PM.
2:30												
12:30												
22:30												
32:30												
42:30												
52:30												
Therm.												

VERTICAL FORCE MAGNETOMETER.

	10 PM	11.	Midn.	1 AM.	2.	3.	4.	5.	6.	7.	8.	9 AM.
7:30												
17:30												
27:30												
37:30												
47:30												
57:30												
Therm.												

	10 AM	11.	Noon.	1 PM.	2.	3.	4.	5.	6.	7.	8.	9 PM.
7:30												
17:30												
27:30												
37:30												
47:30												
57:30												
Therm.												

Form No. 8.

OBSERVATORY at (____________)________day, the ___of

ABSTRACT of Term-day Observations ______________18__

Gott Mean Time.	BAROMETER.		THERMOM.		ELECTROM.		STATE OF THE WEATHER.
	Height.	Temp.	Dry.	Wet.			
10 P.M.							
11.							
Midn.							
1 A.M.							
2.							
3 A.M.							
Means							
4 A.M.							
5.							
6.							
7.							
8.							
9 A.M.							
Means							
10 A.M.							
11.							
Noon							
1 P.M.							
2.							
3 P.M.							
Means							
4 P.M.							
5.							
6.							
7.							
8.							
9 P.M.							
Means							

FORM No. 9.

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